Case study: Integrated resource planning for urban water—*Wagga Wagga*

Institute for Sustainable Futures

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Contents

Figures

Tables

Abbreviations and acronyms

ABS	Australian Bureau of Statistics
ACT	Australian Capital Territory
CMD	customer metered demand
CO_2	carbon dioxide
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DSM DSS	demand-side management decision support system
GHG	greenhouse gas
HSC	HydroScience Consulting
IRP	integrated resource planning
iSDP	integrated supply–demand planning
ISF	Institute for Sustainable Futures
IWCM	integrated water cycle management
NPV	net present value
RWCC	Riverina Water County Council
SWC	Sydney Water Corporation
WSAA	Water Services Association of Australia
WWCC	Wagga Wagga City Council

Acknowledgments

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Summary

What is the purpose of this paper?

The purpose of this document is to assist Australian water resource planners to assess the benefits and feasibility of using the integrated resource planning (IRP) process through a case study demonstration of the regional city of Wagga Wagga in New South Wales (NSW). After introducing the IRP process and the supporting tool, the document details each step of the process, including the collection of data, the development of the supply–demand forecast, the identification of options, and the analysis of the results. In so doing, the case study seeks to reveal both the challenges and insights of the process in a real situation.

Will this paper be useful to me?

This case study complements the *Guide to demand management and integrated resource planning for urban water* (Turner et al. 2010), which has been updated as part of this project. This report will be useful for water resource decision-makers or analysts who are considering initiating an integrated water resource planning process within their own organisations. The case study focuses on the analytical aspects of demand forecasting and the development of demand management options, using the integrated supply–demand planning (iSDP) model for most of the analysis. The paper should therefore be of particular interest to readers wanting to understand these core analytical elements of urban water supply–demand planning and/or those considering using the iSDP model.

What are the take-home messages?

The IRP process can be used for both coastal and inland Australian cities to assess the feasibility of water supply and demand options. It is most useful for cities that are facing a water supply–demand gap and require a detailed analysis of options that can fill that gap. However, as demonstrated by the case study, IRP also has value in regions with uncertain future water availability.

A key recommendation of this case study is that future IRP studies of inland regions should make peak day demand a focus when analysing annual average demand.

The case study also demonstrates that in the NSW context the analytical aspects of IRP and the iSDP model can be used as part of NSW integrated water cycle management (IWCM) planning and are complementary to an IWCM process.

1.1 Introduction

In 2008, the Institute for Sustainable Futures at the University of Technology, Sydney, was commissioned by the National Water Commission to undertake the Integrated Resource Planning for Urban Water Project. This case study report is one of the components of that project. The project has developed tools and materials that are designed to assist water service providers with their longer term water planning. This report documents a case study undertaken to demonstrate the analytical steps of urban water IRP, with reference to the city of Wagga Wagga.

The objectives of the case study were to apply the analytical steps in IRP to the urban water planning issues facing Wagga Wagga and document the implementation of the iSDP model. This includes the analysis of input data, the development of supply–demand forecasts, the identification of options, and the analysis of the results. The case study also aims to assess the usefulness of the IRP framework and supporting tools for water planning in regional centres like Wagga Wagga.

Wagga Wagga is a major inland city in southern New South Wales and is located in the Murray–Darling Basin. Most recent applications of the IRP framework and iSDP model have been to large coastal cities. Therefore, Wagga Wagga was selected as a case study because it provides a good example of how the IRP framework and tools can be adapted to the unique challenges and opportunities faced by inland regional centres.

The report begins by providing background on the IRP process and the iSDP model. It then details each stage of the analysis and concludes with a critical evaluation of the usefulness of the IRP framework in similar regional contexts.

1.2 Approach

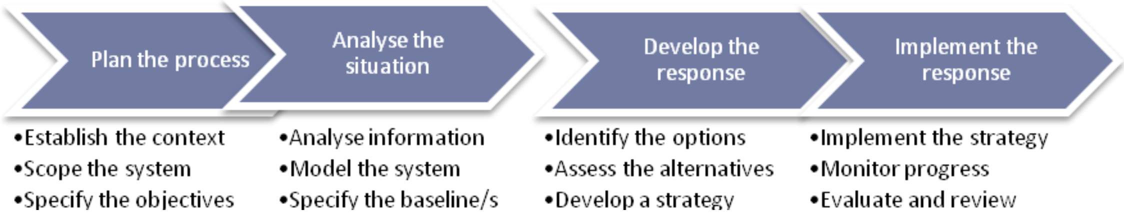
1.2.1 Integrated resource planning

The project methodology is underpinned by IRP, a comprehensive decision-making process directing the effective provision of infrastructure services to cities. The fundamental insight of the process is that cities demand services rather than resources and that options to augment system capacity (for example, through new sources) should therefore be compared alongside options to control demand (for example, through efficient appliances) on an equivalent basis. Over time, IRP has evolved to encompass other important aspects of decision-making about public infrastructure, including public participation, explicit consideration of uncertainty and meeting multiple objectives.

The process broadly involves establishing an agreed definition of the system and its constraints, setting study objectives, developing a detailed baseline forecast of the demand and capacity of the system, and then using it as a basis for assessing a broad range of both supply-side and demand-side options. This ensures that the most cost-effective and sustainable options are considered for implementation.

The Institute for Sustainable Future (ISF) implementation of IRP for supply–demand planning in the urban water sector has been supported by the International Water Association (Turner et al. 2007), the Water Services Association of Australia (Turner et al. 2008), and the National Water Commission (Turner et al. 2010), and is summarised in Figure 1.1.

Figure 1.1 Overview of integrated planning process for urban water



1.2.2 The iSDP model

Decision-support tools fulfil an important role in IRP by facilitating the complex task of assessing and projecting the supply–demand balance of a region, and rigorously comparing the range of demand-side and supply-side options for meeting the study objectives.

The iSDP model was designed specifically for that task. The model was first developed by the ISF in the late 1990s as a demand forecasting and options assessment tool to assist Sydney Water Corporation (SWC) to undertake integrated water resource planning. The model was subsequently improved by SWC and ISF and was later released in 2003 with the support of the Water Services Association of Australia (WSAA). Since its release, the tool has been improved by ISF and CSIRO with various WSAA members in major cities around Australia. To consolidate those improvements and to engage a broader customer base beyond WSAA members, the National Water Commission funded a significant upgrade of the model, which in 2010 was released nationwide to utilities, councils and associated public agencies interested in undertaking integrated water resource planning.

Key features of the model include:

- integrated resource accounting of water, wastewater, energy and greenhouse gases
- integrated cost accounting of costs and avoided costs borne by the customer, the responsible utility, any relevant project partners and society as a whole
- appliance stock models to project shifts in appliance efficiencies subject to new technologies and standards
- dynamic outputs capable of comparing alternative demand, baseline system yield and option yield scenarios
- transparent reporting of model assumptions and embedded supporting reference documents.

The tool is based on a series of Excel workbooks linked to a central database and comprises two integrated modules: a baseline forecast module and an options assessment module. The baseline forecast module projects water demand based on a series of disaggregated *end uses*, each representing individual sectors (for example, the industrial sector) or activities (such as toilet flushing). These component forecasts are each based on a series of assumptions relating to future changes in the mix of sectoral and housing types, and the ownership, usage behaviour and efficiency of fixtures and appliances, among other variables. External analysis is then applied to project the water resource capacity of the existing supply system (or system yield), which is then input to the model. The output is a baseline forecast, which is a ‘business as usual’ or ‘reference case’ projection of the supply–demand balance, assuming no significant intervention by the water service provider or other authorities.

The baseline forecast then forms the basis for the options assessment module. The options assessment module projects the augmented or avoided capacity associated with each option, based on a series of assumptions relating to participation rates and water savings. The economic costs borne by society as a whole, as well as the financial costs borne by the relevant stakeholders, are then projected over the life cycle of each option. These two time-series projections are then expressed as a unit cost ($/kL) to allow the cost-effectiveness of options to be compared.

The final output is a series of metrics and charts that enable a balanced comparison of options, whether they involve augmenting system capacity (for example, commissioning additional reservoirs), avoiding the need for additional system capacity (such as by implementing demand management programs) or a combination of the two. Critically, the analytical outputs of the iSDP model are designed to inform the broader decision-making process that is part of IRP for urban water, which should involve community and/or stakeholder input.

1.3 Methodology

1.3.1 Planning the process

Establishing the context

Wagga Wagga is Australia's fifth largest inland city, with a current population of more than 59 000. The city is situated approximately midway between Sydney and Melbourne and about 2 hours drive west from Canberra. Wagga Wagga is on the Murrumbidgee River and sits in an alluvial valley that is in the upper reaches of the Riverina plain. The city is an educational, retail, industrial, retirement and military hub within the Riverina region.

Riverina Water County Council (RWCC) is responsible for managing the urban water supplies for four local government areas, of which the Wagga Wagga City Council (WWCC) is by far the largest. Wastewater and stormwater are both the responsibility of the WWCC. Water is sourced by pumping from the Murrumbidgee River (44 ML/d) and from borefields to the east, west and north, each with a nominal rated capacity of 25 ML/d (Finlayson 2010). In 2004–05, the Wagga Wagga urban area was using 20 ML/d in winter and up to 100 ML/d in summer. Evaporative coolers, air-conditioners and outdoor irrigation are important contributors to peak demand.

Driver 1: Constrained water availability and climate change

Wagga Wagga's urban water supply is sourced from the Murrumbidgee River and from a series of deep aquifers. The aquifers have a connection to the channel of the Murrumbidgee River and are replenished by river flows. The relationship between the flow regime of the river and the availability of groundwater continues to be investigated; however, the interconnection means that constraints on available water supplies in the region apply to both surface and groundwater sources.

Wagga Wagga is one of a string of urban and agricultural settlements, both upstream and downstream, that are dependent on the Murrumbidgee River and its associated groundwater aquifers. Although water availability in the region has been high in the past, in the future it is expected to be significantly more constrained. This is due to both the reversal of historical overallocation of water and the impact of climate change across the Murray–Darling Basin.

The Murrumbidgee River was one of the catchments covered by the CSIRO's Murray–Darling Basin Sustainable Yields Project, and the final report on the region was published in 2008 (CSIRO 2008). The project linked modelling of rainfall–runoff to groundwater modelling and water use across the region under various climate and development scenarios. Connectivity between surface and groundwaters was included. The scenarios considered included one based on a continuation of the 1997–2006 drought, as well as scenarios incorporating best estimates projections of water availability based on climate change modelling.

The CSIRO's Sustainable Yields study found that the long-term average surface water availability in the Murrumbidgee River was 4270 GL per year. About 10% of this total came from interbasin transfers from the Snowy Mountains Hydro-electric Scheme. On average, 53% of the total surface water was diverted for use in the region, of which Wagga Wagga urban use was only tiny fraction. The study also found that, if the drought conditions from 1997 to 2006 continued, the average surface water availability would reduce by 30%. CSIRO applied a range of climate models to the catchment. It found that the best estimate was a 9% decrease in runoff by 2030 (significantly less that the impact of continuing drought), but that a level of uncertainty about future climate remained.

The guide to the Murray–Darling Basin Plan (MDBA 2010) indicates that Murrumbidgee surface water extractions will need to decrease by between 32% and 43%. The plan holds 'critical human need' as the highest priority for water. However, it will be the NSW Government's interpretation of the Murray–Darling Basin Plan that defines the surface water constraint for Wagga Wagga.

The local aquifer that Wagga Wagga relies on for its groundwater supply, Zone 2 of the mid-Murrumbidgee groundwater system, is only 20 kilometres long and exhibits numerous signs of stress (Finlayson 2010). It has highly intensive demands compared to adjacent aquifers, and declining water levels in the bores and reduced outputs (Finlayson 2010). A current hydrogeological modelling study, as part of RWCC's IWCM planning (see Driver 5 below) is addressing the question of sustainable yields from the existing bores and the Zone 2 aquifer.

The CSIRO Sustainable Yields study indicated that in the mid-Murrumbidgee groundwater system a stable groundwater level would be attained at an extraction level of about 40 GL/year (about 85% of the current usage). However, reductions might be expected to be higher in Zone 2 (Finlayson 2010).

Any reductions in groundwater or surface water allocations are likely to leave town water supplies secure. The NSW Department of Environment, Climate Change and Water has stated that towns with high-security water allocations would be buffered from reductions in inflows due to climate change (DECC 2008), and the Murray–Darling Basin Plan will make 'critical human needs' the top water priority (MDBA 2010). However, during the recent drought, the NSW Government temporarily cut Wagga Wagga's town-water allocation from the river by approximately half and imposed restrictions on outdoor water use. Given this, the question of water availability for urban water use in Wagga Wagga is likely to remain a question of government allocation, and future decisions in this regard will be made in the context of reduced water availability in the Murrumbidgee River system more generally. By looking at the potential for demand management, this study seeks to facilitate informed consideration of the costs and other implications of decreasing future town water allocations.

Driver 2: Urban growth

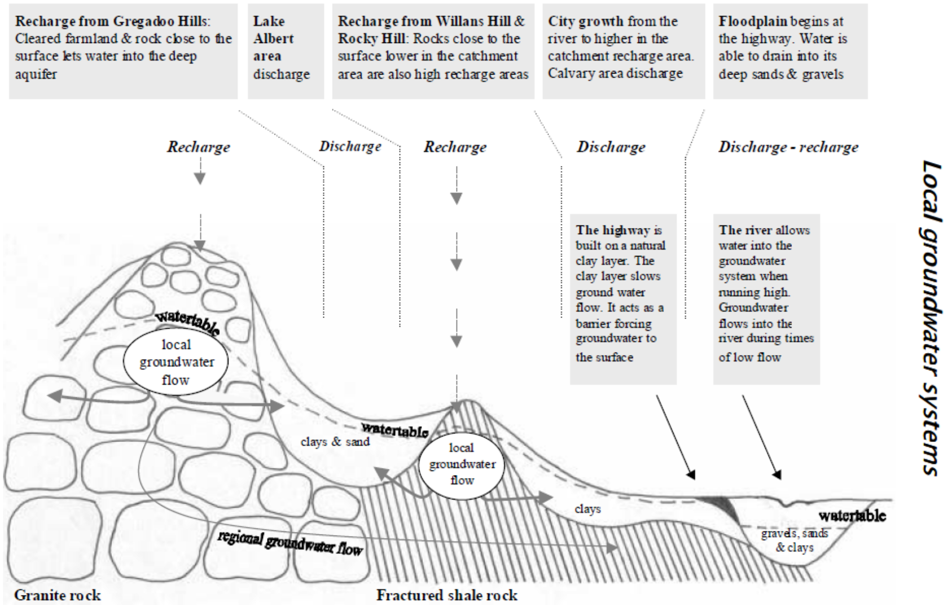
Although the boom growth period that the city experienced during the 1970s is unlikely to be surpassed, the NSW Department of Planning is expecting moderate population increases to 2030, with an annual growth rate of 0.5–0.6% per annum over the period. Over the past two decades, growth in housing has been higher than population growth due to declining occupancy rates, a feature in most Australian urban areas. Between the 1991 and 2006 censuses, residential occupancy in Wagga dropped from 2.8 to 2.5. Occupancy is important, as water uses such as garden watering are driven by housing numbers rather than population. Growth in the industrial sector of the city is also expected, and several large customers are currently or soon to be established.

The urban growth will lead to new demands for water services in the city. The projected growth in services then necessitates supply–demand planning to meet that demand. Through developing demand projections and options, this study aims to support supply–demand planning for Wagga Wagga.

Driver 3: In-town groundwater salinity

Wagga Wagga's naturally saline upper watertable has risen significantly since settlement owing to historical poor land management practices, including excessive irrigation (both rural and urban) and deforestation. The consequence has been waterlogging and salt damage to private and public buildings, roads, and water and stormwater infrastructure, resulting in estimated repair and maintenance costs of $183 million in present value terms over a 30-year period (NSWDLWC 2000).

Figure 1.2 Schematic of groundwater movement in Wagga



Source: Wagga Wagga City Council (2001).

Because outdoor use is a large component of water consumption in Wagga Wagga, this study assesses a range of outdoor demand management options. Options targeted at reducing outdoor water consumption also present an opportunity for managing in-town salinity impacts.

Driver 4: Reducing greenhouse gas emissions

To address the issue of climate change, water utilities need to look at their energy use and direct greenhouse gas (GHG) emissions in parallel with the impact of climate change on their water demand and supply balance (Fane et al. 2010). As in all regions, minimising and if possible reducing GHG emissions should therefore be considered a driver for action in water planning for Wagga.

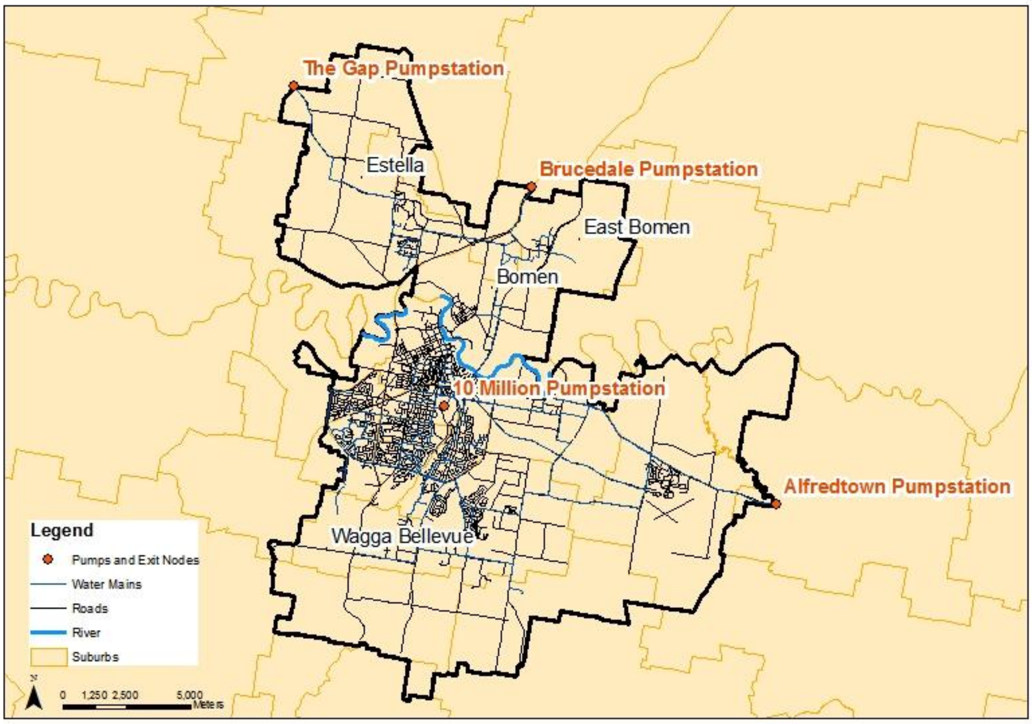
Driver 5: Concurrent integrated water cycle management planning

The NSW Office of Water requires council-owned water utilities in NSW to prepare IWCM plans. RWCC undertook an IWCM planning process concurrently with this case study. The case study therefore aims to produce analyses that are useful for the IWCM planning.

Scoping the system

The scope of the study is limited to the assessment of the potable water demand and supply capacity for the city of Wagga Wagga. Consequently, the study region has been limited to the Wagga Wagga system, which is bound by the suburbs of Estella and Bomen to the north, Alfredtown to the east, Ashmont to the west, and Bourkelands to the south. For analysis purposes, the network boundary has been defined by the pumpstations at The Gap, Brucedale and Alfredtown and by the 10 million gallon storage as marked in Figure 1.3.

Figure 1.3 Study region boundary



The study focuses on the long-term planning horizon. As such, it has adopted a period beginning in the 2009–10 financial year and ending in 2049–50, with an annual time increment. The study addresses an economic question, so a whole-of-society perspective should be considered in relation to costs. Therefore, the study assesses the costs and benefits borne by the utility, the customer and any third-party partners. Ideally, externalities should also have been included. However, due to the limitations of scope, externalities were not quantified as part of this study.

Specifying the objectives

Constraints

Consistent with the objectives of IRP for urban water supply–demand planning and the Wagga Wagga context outlined above, the alternative strategies considered in this study were limited by the following constraints:

- *In relation to surface water supply, the town water allocation cannot be exceeded*. The alternative scenarios must not withdraw water in excess of their allocations, as stipulated by the NSW Department of Environment, Climate Change and Water.
- *In relation to groundwater water supply, neither the town water allocation nor the physical limits to groundwater can be exceeded*. The alternative scenarios must not withdraw water in excess of their allocations. Current hydrogeological modelling is helping to define the physical limit of groundwater availability.
- *In relation to water demand, demand for water services in the region is to be met*. The alternative strategies must provide sufficient water to meet the forecast water service requirements of the future population, either by increasing supply or by managing demand.

Principal objectives

Within the constraints outlined above, the principal objectives of the study were to:

1. identify options that may be economically cost-effective from the perspective of the society as a whole
2. assess the potential to reduce demand cost-effectively in order to meet the water supply constraint in a potential future scenario in which allocations need to be reduced
3. identify options that may be financially cost-effective from the perspective of the water supply utility (RWCC).

The cost-effectiveness of options was evaluated in this study based on the levelised unit cost of water. This is the present value of the cost of the option (whether to society as a whole or to the water utility) divided by the present value of the annual volume of water saved or supplied by the option (Dziegielewski et al. 1992:109, Fane et al. 2003, Herrington 2006). Based on the levelised unit cost, an option's cost-effectiveness can be assessed relative to the marginal cost of water supply in the study region.

Secondary objectives

The secondary objectives for the study were to:

1. minimise potential amenity losses due to options that affect lawns and gardens
2. identify options that reduce outdoor demand and would also have a positive impact on urban salinity
3. identify options that that could reduce GHG emissions.

Amenity loss and reduced outdoor demand in relation to in-town salinity were assessed qualitatively, while GHG emissions where estimated quantitatively in terms of total emissions to 2050 in carbon dioxide equivalents (CO_2-e).

1.3.2 Analysing the situation

Collecting the information

After the analytical basis for the study was established, the next stage involved gathering, processing and analysing sufficient data to inform the analysis.

The key data inputs to the analysis were:

- bulk meter data—high-resolution, aggregated consumption data recorded at the water treatment plant
- customer meter data—lower resolution consumption data recorded at individual customer connections
- demographic data—historical and projected population, household occupancy and other attributes of the region
- end-use data—customer surveys and measurement studies to characterise water-use behaviour
- climatic data—meteorological records characterising rainfall, evaporation rates, temperature etc.

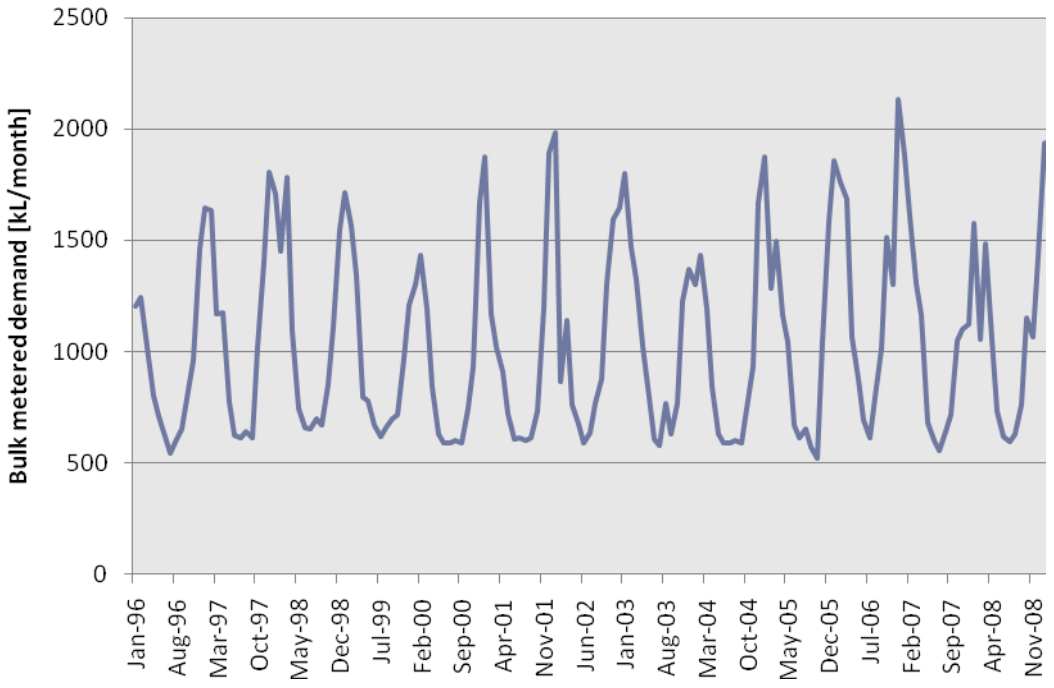
The analyses performed and their results are detailed below.

Bulk meter data

Bulk meter data represents the total water produced by the system. This data can be compared with the customer metered demand (CMD) data to determine system losses. Bulk meter data is typically available at more highly resolved time steps than CMD data and therefore is a more accurate basis for analysing time-variable influences on demand, such as seasonality and the effect of major events such as drought.

Using its existing bulk meter data collection system and a subsequent round of data cleansing, RWCC was able to provide monthly time series of bulk water delivered to the Wagga Wagga system, as shown in Figure 1.4.

Figure 1.4 Monthly record of bulk water delivered (kL/month)



Note: The system retains several anomalies that suggest spurious meter reads.

ISF recommends that utilities starting a water planning process invest time in improving bulk meter data accuracy as an initial step.

Customer meter data

Customer meter data is used for several purposes; first, it is compared with bulk water demand to help determine system losses between the bulk meter and customer connections; second, it is used as the calibration point for the modelling of residential end-uses; third, it is used as direct input in the model for the non-residential sector.

Customer meter data has historically been collected for billing purposes and, although the quality of the data varies, some form of preprocessing and data validation is usually required.

The following preliminary tests were applied to the customer meter data to determine where corrections and/or data cleaning were required:

1. reversed read dates
2. read dates outside expected range
3. read period outside expected range
4. read period discontinuous
5. negative consumption
6. consumption outside expected range.

The tests revealed a significant proportion of records with reversed dates and negative consumption. Those records were subsequently identified as metering corrections, which were removed by switching the dates and summing the records by read period to yield a corrected meter read.

Where tests identified clearly spurious data, which for the most part involved those records identified in the date range test, the offending records were identified and excluded from the dataset.

The quarterly customer meter data was then 'binned' or apportioned to individual months to provide a better indication of the temporal distribution of demand. This is possible because customer meters are read over different periods that are spread roughly evenly across the year. The process is associated with some artificial smoothing of the time-series, but for large numbers of customers that effect is less pronounced.

The process for binning customer meter data was as follows:

1. The mean daily consumption rate for each quarter was calculated for each individual customer.
2. The monthly consumption for each customer was then calculated by adding the daily consumption rates that fall within that month. If the meter was not read in that month, the monthly consumption would simply be the daily consumption rate multiplied by the number of days in that month, whereas if the meter was read within that month the monthly consumption would represent a weighted average consumption rate prorated with the number of days of each intersecting meter read period that fell within the month).
3. The significant errors of the binning process were then reduced by calculating the mean binned monthly consumption by customer type to provide a smoothed estimate of monthly time-series demand.

For more details on the process of binning, refer to Appendix B of the *Guide to demand management and integrated resource planning* (Turner et al. 2010).

The binned monthly consumption for both single and multiresidential households is shown in Figure 1.5 and Figure 1.6. The relatively high seasonality is a consequence of the high temperatures and evaporation rates in the summer months. Note that the available data in the 2003–04 period appears to have been incomplete and should be considered as a data anomaly.

Figure 1.5 Total customer metered demand, single residential households

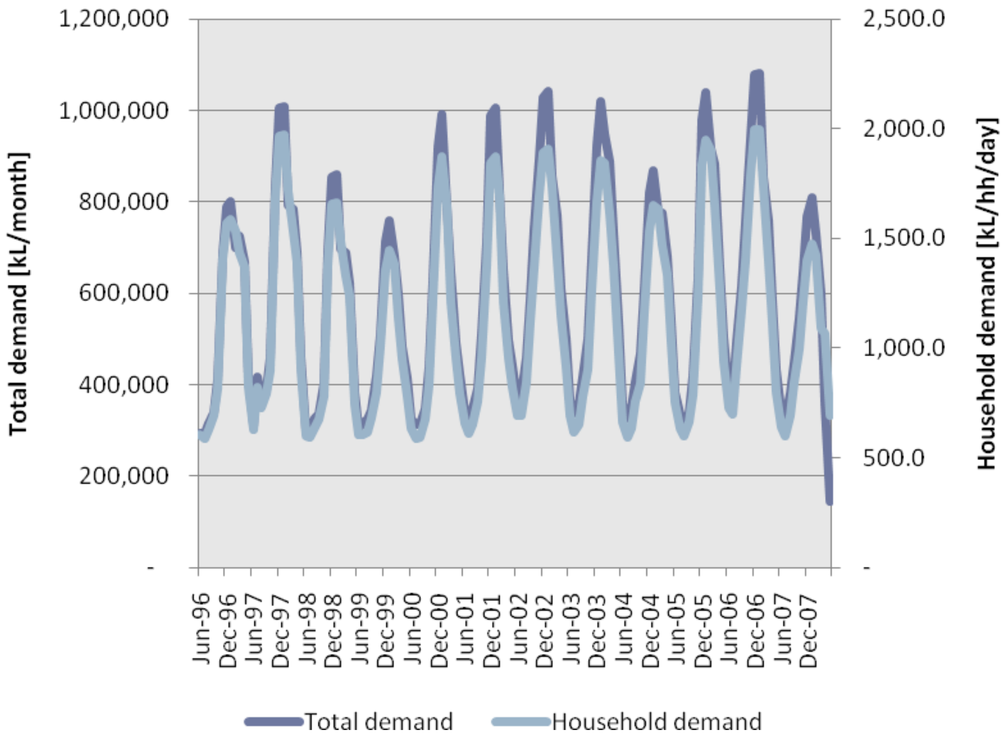
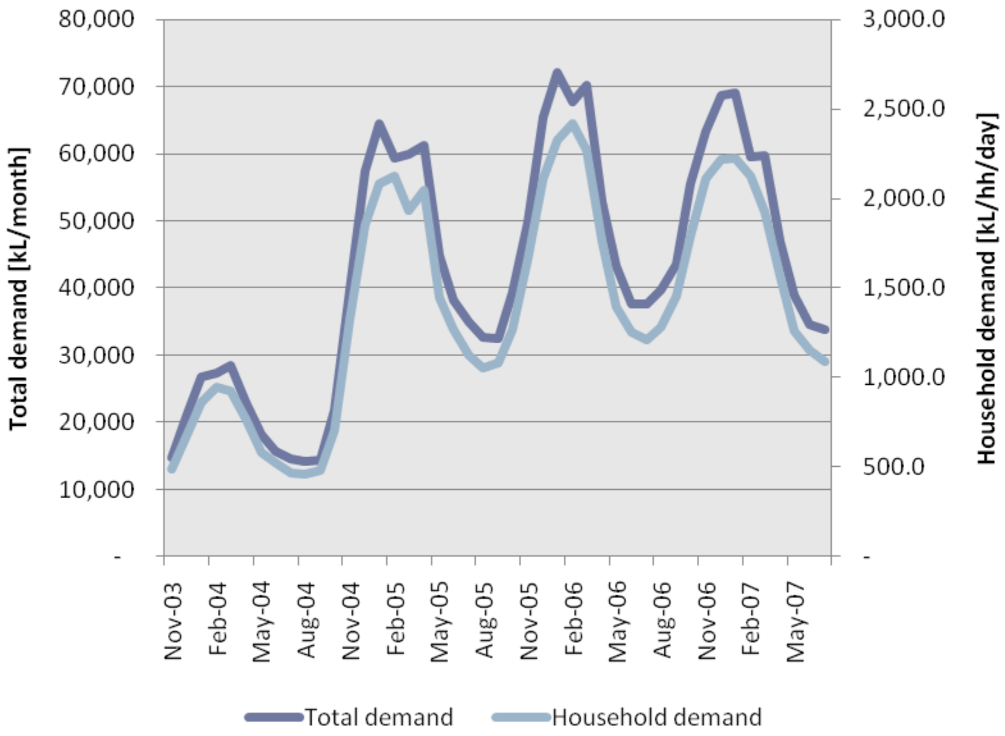


Figure 1.6 Total customer metered demand, multiresidential households



Demographic data

The demographic characteristics of the service area are the major influence on future demand and therefore the foundation of the analysis.

The key demographic inputs to the iSDP model are:

- historical census data characterising the population, dwellings, dwelling structure (detached, semidetached, flats or apartments) and dwelling occupancy (occupants per dwelling) etc.
- projected population, dwellings and occupancy levels.

This data was entered into the region sheet within the model and formed the basis of the water use projections.

The historical census data is typically provided by the Australian Bureau of Statistics in a variety of resolutions, ranging from highly aggregated regional data tables for periods prior to the 1996 Census, to the geographically referenced datasets of subsequent censuses that provide data by census collector district (approximately 500 households).

The projected populations, dwellings and occupancy ratios are typically provided by the relevant state authority (in this case, the NSW Department of Planning) and are typically available by statistical local area (approximately 15 000 households) (NSWDP 2005).[1]

As the regions of the historical and projected datasets rarely align with the service area in question, spatial analysis is necessary for both datasets.

To begin, a spatial database query was applied to select those statistical collector districts in the most recent ABS census basics dataset (ABS 2006) with centroids lying within the service area boundary. After the districts were selected, the population and household counts by dwelling structure were then summed for single residential households (those households living in detached dwellings) and multiresidential households (those living in other dwelling structures, including semidetached dwellings, flats and apartments).

This process was then repeated for the demographic projections (obtained from the Department of Planning) to derive an annual time-series forecast of population. As no projections of dwelling numbers were available, these figures were derived by assuming that household occupancy within single and multiresidential dwellings will remain unchanged in the future.

The historical time series to 1960 represents the aggregated population of Wagga with an unspecified boundary, so this data was drawn directly from the dataset. In the absence of readily available dwelling counts, the figures were derived by applying nationwide historical occupancy levels.

The annual time series were then entered into the region sheet within the iSDP model, which applies the recent census year data as the base year and the historical and projected time series as forecast and hindcast factors to provide a consistent time series. Those projections resulted in a characterisation of key demographic attributes for the study region for the period from 1960 to 2050.[2] The projection of population in single and multiresidential dwellings is shown in Figure 1.7, while the numbers of dwellings within each housing type are shown in Figure 1.8.

[1] Some more highly resolved projections may be acquired from various state government agencies.

[2] Note: The hindcast to 1960 is necessary to establish the mix of ages of dwellings and appliances for stock modelling purposes (detailed in Section 7.3.2).

Figure 1.7 Historical and projected population, single and multiresidential households

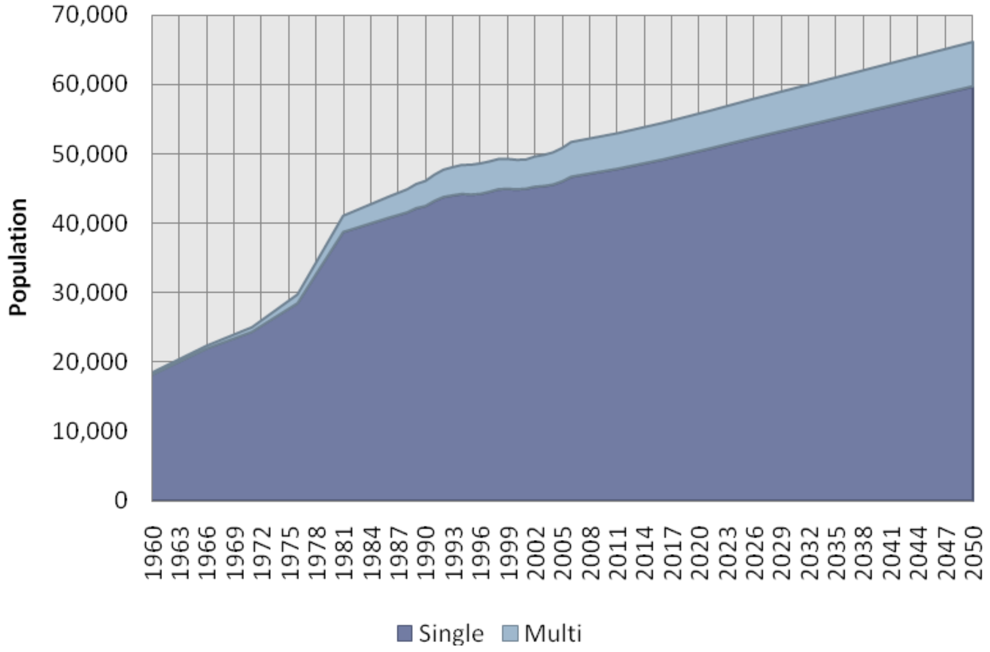
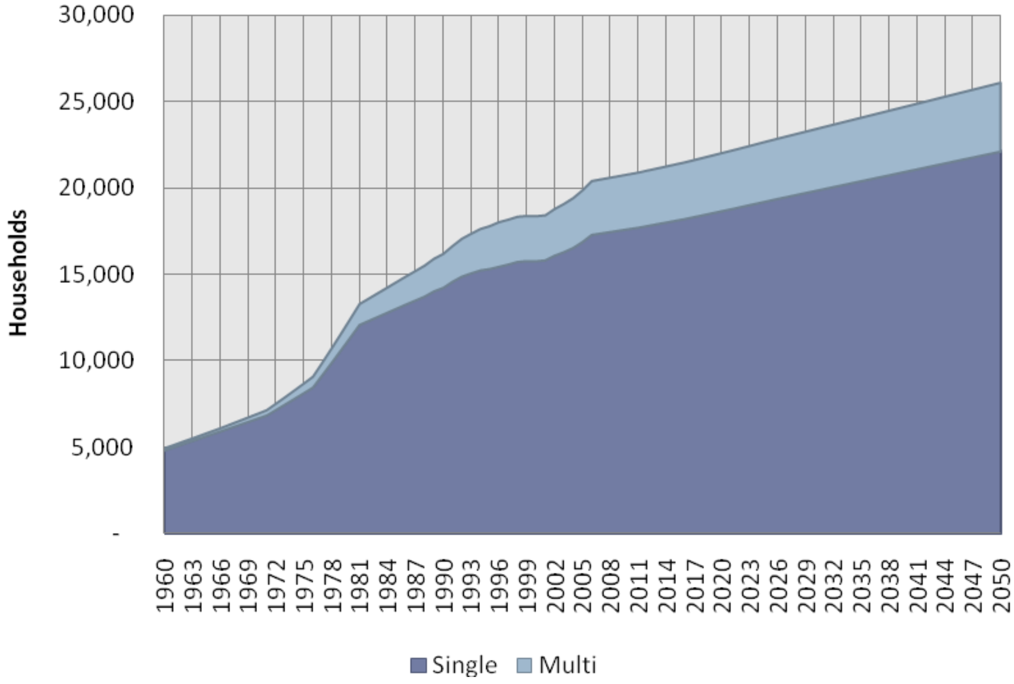


Figure 1.8 Historical and projected number of households, single and multiresidential dwellings



End-use data

Customer surveys and measurement studies characterising water-use behaviour are becoming increasingly available to facilitate a deeper understanding of the influences of water demand.

Given the absence of any studies of this kind within the study area, the model relies on the best available proxy, pending more region-specific data. Key sources included:

- a state-wide survey series of household ownership for various water-consuming appliances, conducted since 1990 (ABS 2007, 2008)
- a state-side sales inventory for a number of appliances, conducted by Energy Efficient Strategies over the period from 1993 to 2005 (EES 2006)
- an extensive survey of household water use behaviour and an end-use measurement study, both conducted by Yarra Valley Water (Roberts 2004, 2005)
- several complementary surveys in Sydney and Perth (Loh and Coghlan 2003).

This data has been built into the iSDP model and is available as a default. Where no suitable proxy was available, ISF contacted local businesses. A detailed account of the model assumptions has been provided as Appendix 7B.

ISF recommends that, in regions with water availability constraints, studies be undertaken to confirm specific local end-use assumptions and regionally specific variables. For instance, the assumed shower flow rates are both highly sensitive and regionally specific (typically, they are dependent on local water pressure) and thus a priority data gap. Evaporative cooler use and settings are also highly specific to local conditions.

Climate data

Climate data is used both within the baseline forecasting module and within the options assessment module.

Thirty-year daily temperature, rainfall and pan evaporation records were obtained from the Australian Bureau of Meteorology for the weather station at Wagga Wagga AMO. That data was inserted into the outdoor end-use sheet for use in calculating the outdoor demand component of the baseline. The same data was also used in the various option sheets that relate to outdoor water use to assess potential yield from demand management options designed to reduce outdoor water use.

Modelling the system

Modelling system yield

Two system yield scenarios were assessed in the study: the ‘licensed allocation’ scenario, which assumes that the full historical town water allocation will be maintained, and the ‘reduced allocation’ scenario, which assumes reduced allocations for both surface and groundwater.

The ‘licensed allocation’ scenario is 7000 megalitres per annum (ML/a) available from surface water sources and 14 000 ML/a from groundwater sources, providing a total allocation of 21 000 ML/a.

The ‘reduced allocation’ scenario assumes a reduction to 50% and 70%[3] of the surface water and groundwater sources, respectively, providing a total allocation of 13 300 ML/a.

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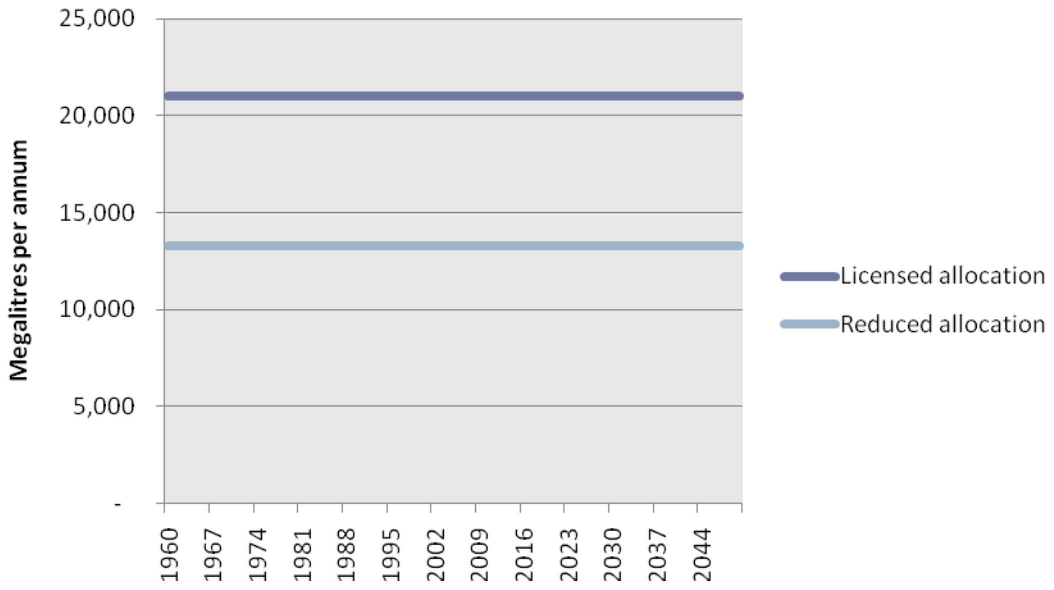
[3] Note that the 70% is an assumption made for the purposes of this case study. As part of the current IWCM planning process by RWCC, there is a hydrogeological modelling study addressing the question of sustainable yields from the existing borefield.

Figure 1.9 Baseline system yield scenarios (ML/a)



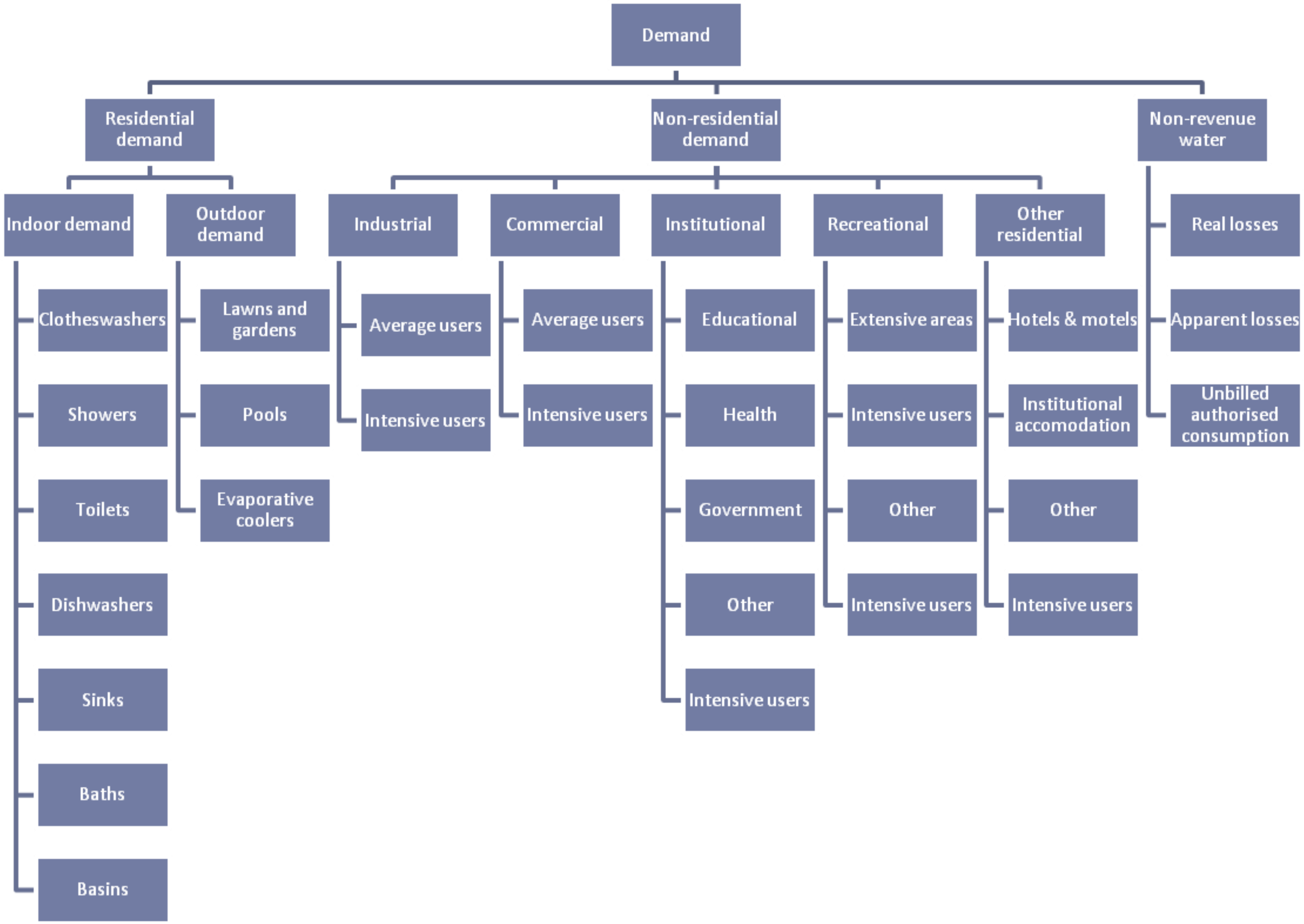
Modelling system demand

The demand forecast broadly comprises residential demand, non-residential demand and non-revenue water, as depicted in Figure 1.10. Within residential demand, end uses are split between indoor and outdoor, with outdoor demands being far more dependent on climate variables. The calculation of residential demands is based on demographics, end use and stock modelling undertaken within the model.

The non-residential demands are categorised as ‘industrial’, ‘commercial’, ‘institutional’, ‘recreational’ or ‘other residential’. Further subsectors break down demands according to end-use type (for example, ‘education’ or ‘hotels’) and level of water use (such as average user or intensive user). The model user is required to process the non-residential customer demand data, such that it is broken down into these categories, so that it can be entered into the model.

The non-revenue water category comprises ‘real losses’, ‘apparent losses’ and ‘unbilled authorised consumption’. The model determines the total volumes of non-revenue water from the difference between the bulk water and customer metered demand. The model user is required to input factors into the non-revenue water end-use sheet so that the model can then determine the likely breakdown of real and apparent losses and unbilled authorised consumption.

Figure 1.10 Demand sectors, subsectors and end uses



Residential demand

The residential component of the model comprises a series of individual end uses, each representing a water-consuming activity around the home.

The analysis of each end use is based on a series of assumptions relating to the usage behaviour, the appliance stock mix, and the associated technology (or efficiency). These are combined to determine the demand associated with that end use, as described by the function:

$$\text{Demand} = \text{Usage} \times \text{Stock} \times \text{Technology}$$

The major indoor end-uses, including showers, washing machines, dishwashers and toilets, use an appliance cohort stock modelling approach. This involves simulating the appliance stock over time, based on a series of individual cohorts purchased in each year. The result is a series of region-specific stock models for each end use. (For further details on stock modelling and its use in demand forecasting and options development, refer to Turner et al. 2010.) Evaporative coolers are shown as 'outdoor demand' in Figure 1.10, in recognition of the location of this water use and its seasonal nature. They are classified in this manner despite the benefits of cooling occurring indoors. Evaporative coolers were modelled based on the available literature as well as interviews with a number of suppliers and technicians servicing coolers in the region.

The other outdoor end-uses, including lawns, gardens and pools, use a mass balance modelling approach based on area and behaviour assumptions, coupled with historical climate data. This involves simulating both the losses from the lawn–garden–pool system (evaporation, transpiration etc.) and the gains to that system (rainfall, potable demand etc.). Any difference between the losses and gains to that system results in a change in the system's storage (for example, the soil mass or the water reservoir in a pool).

See Appendix 1A: Baseline assumptions for details of the end-use assumptions used in the study.

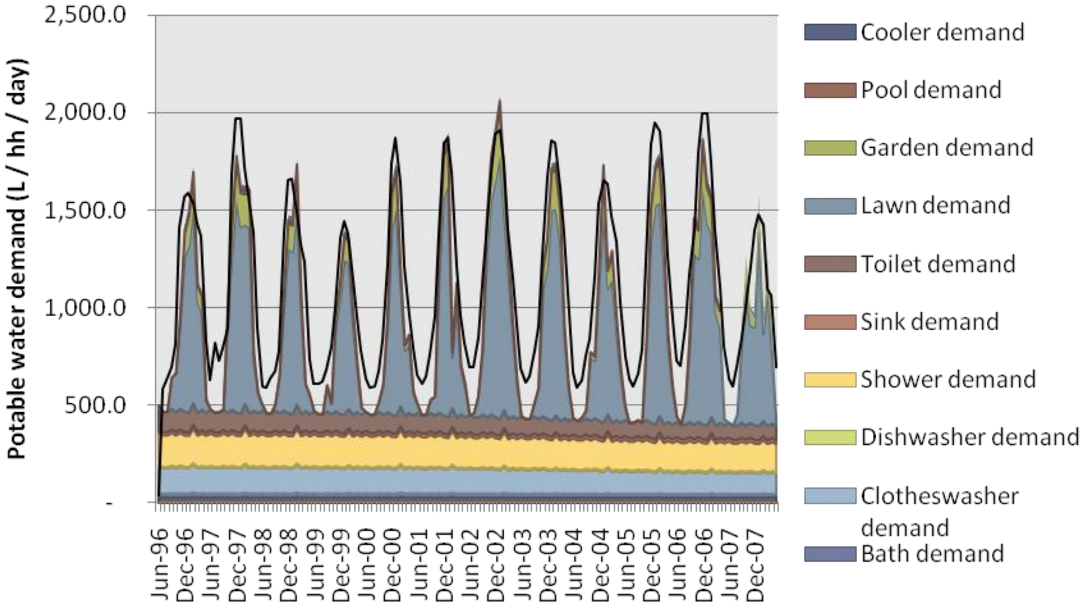
Residential calibration

After the dynamical or 'bottom up' model of residential demand has been created, the outputs of the model are then calibrated to the customer meter data (analysed above, under 'Customer meter data'), to form the 'top down' or empirical basis for demand. As the estimate of baseline lawn and garden water demand is the most sensitive and variable parameter in the residential demand forecast, this baseline component is fitted to customer metered demand using an 'overwatering' factor. A graphical depiction of this process is provided below.

Figure 1.11 shows the time series of the modelled indoor residential end-uses (flat sections of the graph unaffected by seasonal demand) and the modelled outdoor demands (peaked components of the graph). The black line shows the total residential customer metered demand for that period. The calculation of lawn and garden demand includes a factor that can be used to account for overwatering. In this graph, no overwatering factor is added and it therefore shows 'ideal' watering behaviour.

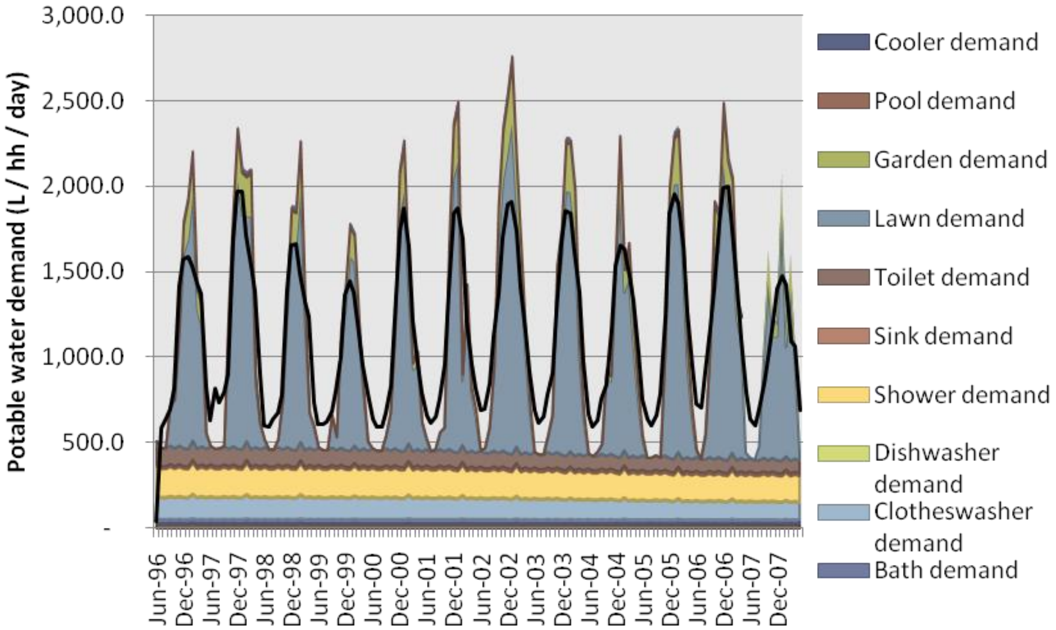
While the soil moisture balance was undertaken on a daily basis, the estimated consumption was binned into months to allow calibration with the monthly binned customer meter data. Figure 1.11 and Figure 1.12 show daily rates to avoid artefacts caused by figures for different days per month.

Figure 1.11 Time series of modelled residential end-uses—not calibrated to customer metered demand



In Figure 1.12, the overwatering factor has been added so that the sum of the modelled end-uses (indoor and outdoor) matches the total customer metered demand. This is the calibrated version. It indicates some overwatering in current watering practice in Wagga Wagga, but also that the larger gains are likely to be made in changing garden type than in perfecting watering behaviours. Note that the customer metered demand is recorded at quarterly intervals, and the process of binning this data into monthly time series has the effect of levelling the troughs and peaks. Therefore, the difference between metered and modelled demand on a monthly basis is exaggerated.

Figure 1.12 Time series of modelled residential end-uses—calibrated to customer metered demand



Non-residential demand

The non-residential demand components of the model are much simpler. Non-residential customer metered demand must be preprocessed so that properties are categorised according to end-use type, and the highest water users in each category are extracted. Those categories can then be entered into the relevant non-residential end-use sheets in the model. The breakdown of non-residential end use categories is outlined in Figure 1.10.

Extracting the highest water users in each category has several purposes: first, to ensure that average water consumptions can be determined for each category without being skewed by very high water users; second, to identify the high water users to determine where large water savings might be made through demand management interventions; third, to ensure that water demand from those users can be projected individually, based on local knowledge. For example, a factory may be making a major extension of its processes or a specific industry might be closing down, and those events may significantly affect water use in the respective categories. Also, some businesses and buildings are likely to expand with population growth and others are not, so, depending on the characteristics of each customer, the predicted demand for each individual intensive customer is either pegged to population growth or fixed to remain constant into the future.

Once entered into the model, demand for each subsector is forecast by the model by projecting the number of subsector customers in proportion to population growth and then applying the mean annual consumption per customer over an appropriate calibration period.

Processing the non-residential data and determining the average water use per property for the various categories (such as schools, hospitals etc.) also provides an insight into the relative water use of each sector and any trends that may have been occurring in average water usage per property in each sector. These observations become useful when selecting demand management options that target specific sectors. A selection of graphs that were prepared during the data preprocessing is shown below. Figure 1.13 shows the peaky nature of water demand for educational facilities in Wagga, with average demand oscillating between 200 kL/property/month and 1000 kL/property/month. The peaks are likely to be due to outdoor irrigation, which is primarily required during the hotter months. Demand management programs that target irrigation efficiency are likely to help reduce the peaks.

Figure 1.13 Average monthly water consumption per property—'institutional' category—education

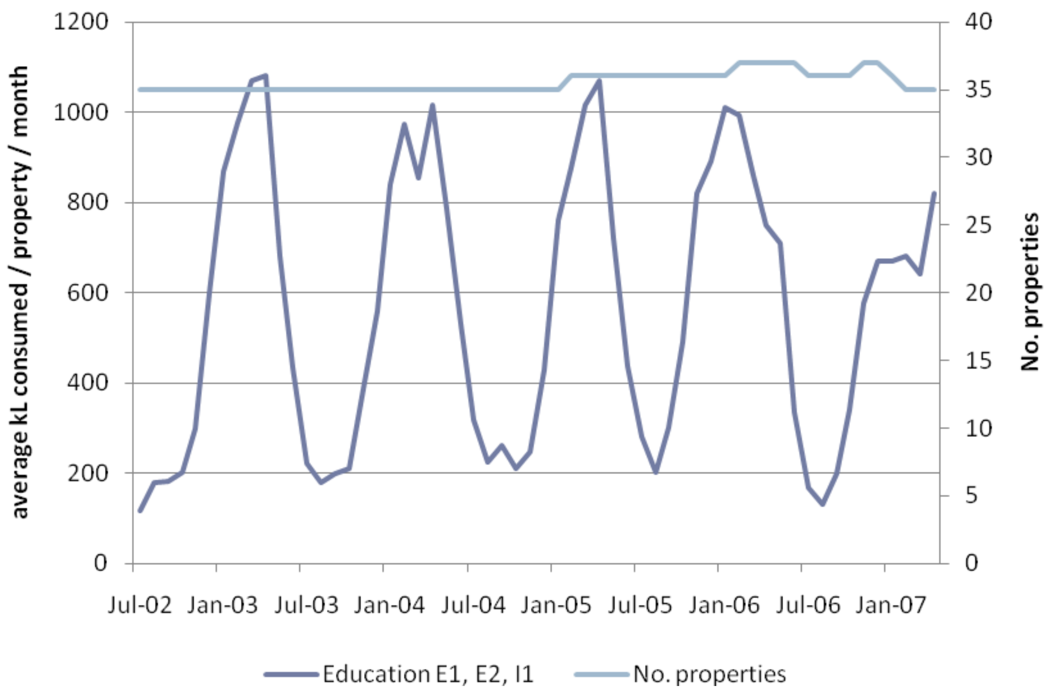


Figure 1.14 Average monthly water consumption per property—'other residential' category—hotels and motels

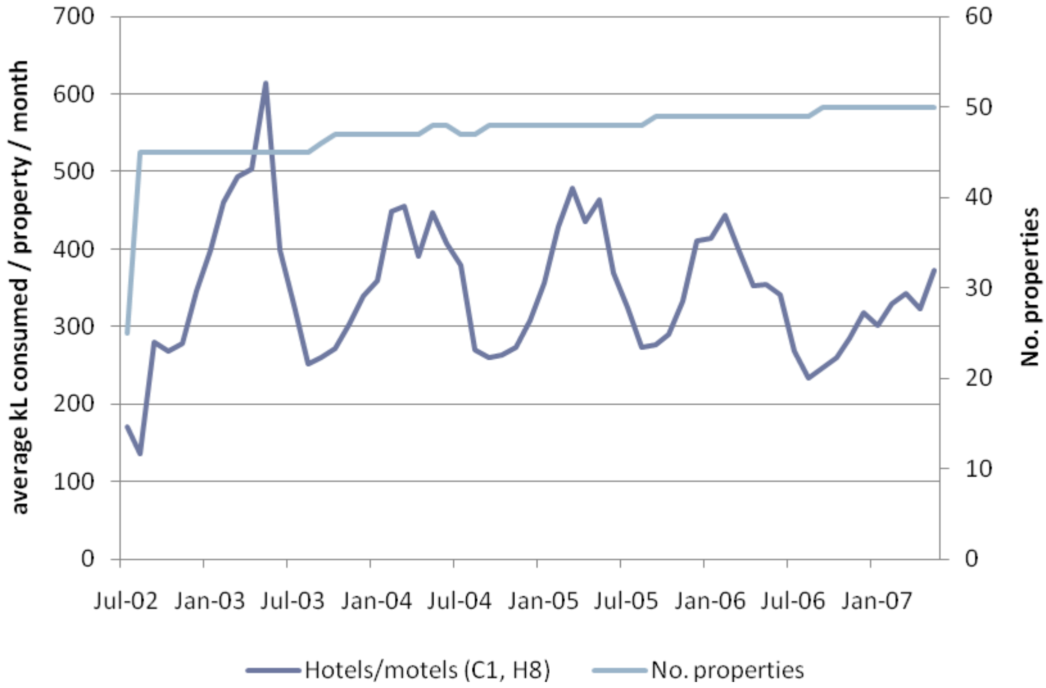
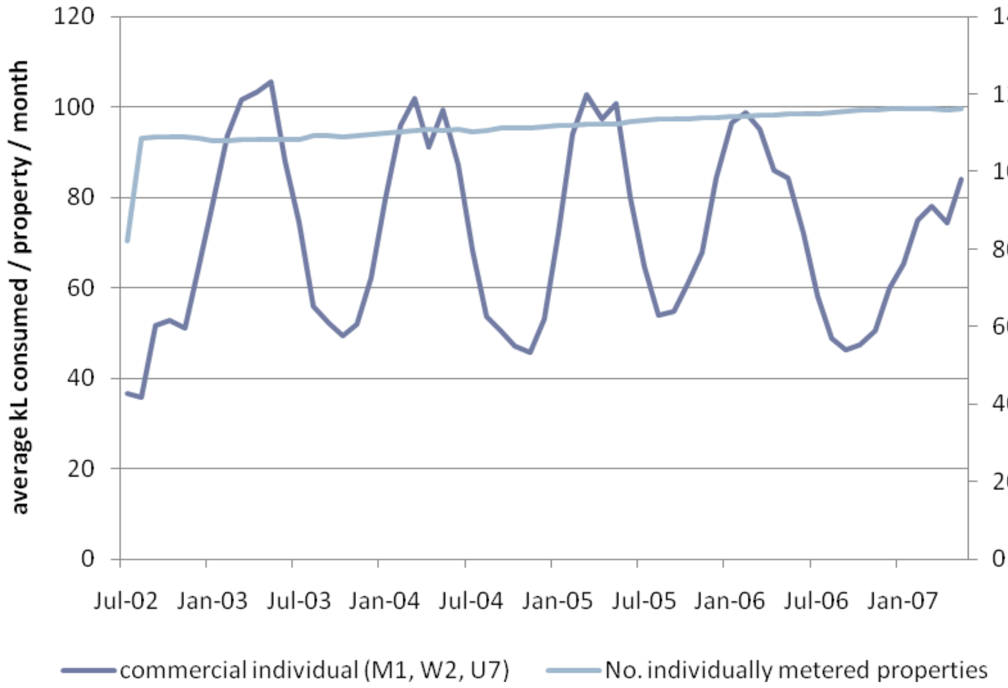


Figure 1.14 shows the average water consumption for hotels and motels between 2002 and 2007. This graph appears to show that the seasonal peaks in this sector are diminishing, but that may be an artefact of the data. The graph shows that there are approximately 50 properties in this category that could be targeted for improved water management.

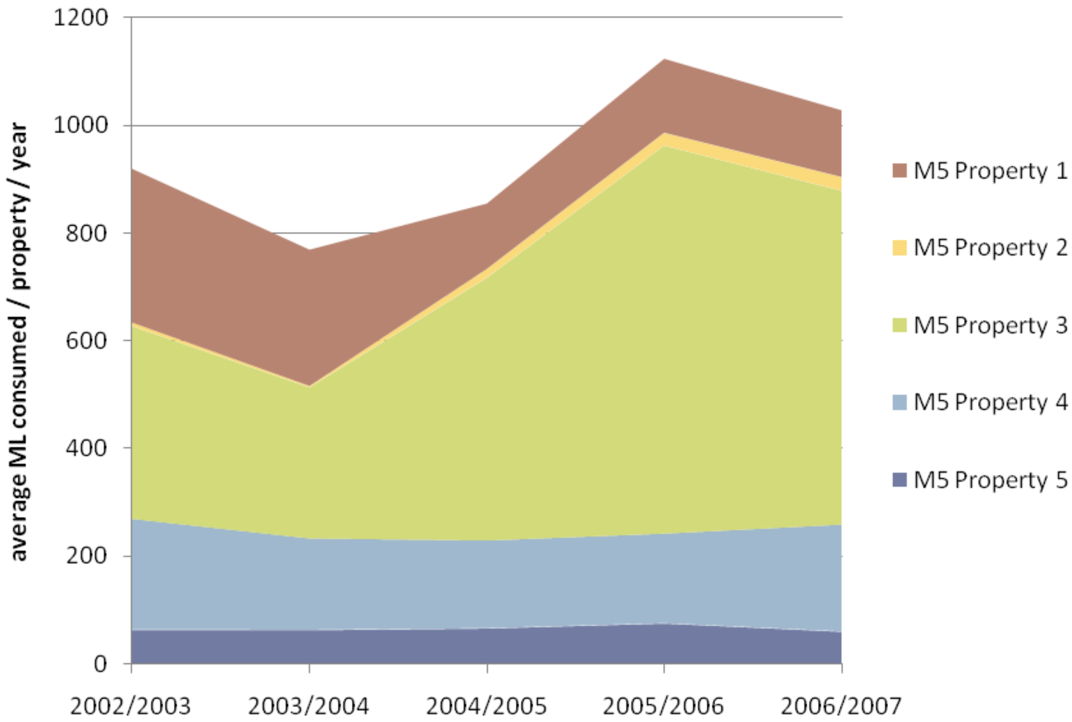
The average monthly water consumption for commercial properties is shown in Figure 1.15. These properties also appear to show a seasonal peak in water use, with the average doubling from 50 kL/property/month up to approximately 100 kL/property/month. This would be due to a combination of evaporative air cooling and outdoor irrigation.

Figure 1.15 Average monthly water consumption per property—commercial properties (individually metered)



Apart from the analysis of individual sectors, high water users were also extracted from the data. Figure 1.16 shows the water consumption of the largest industrial users in Wagga Wagga. The volume of water used at a number of these properties is significant, and any opportunities to improve water-use efficiency could be correspondingly significant. Another opportunity would be to determine the reason for the increase in consumption for property no. 3, as it may represent a change in activities within the property, which could be readjusted to reduce water use to its former levels.

Figure 1.16 Average annual water consumption—'industrial' category—high water users

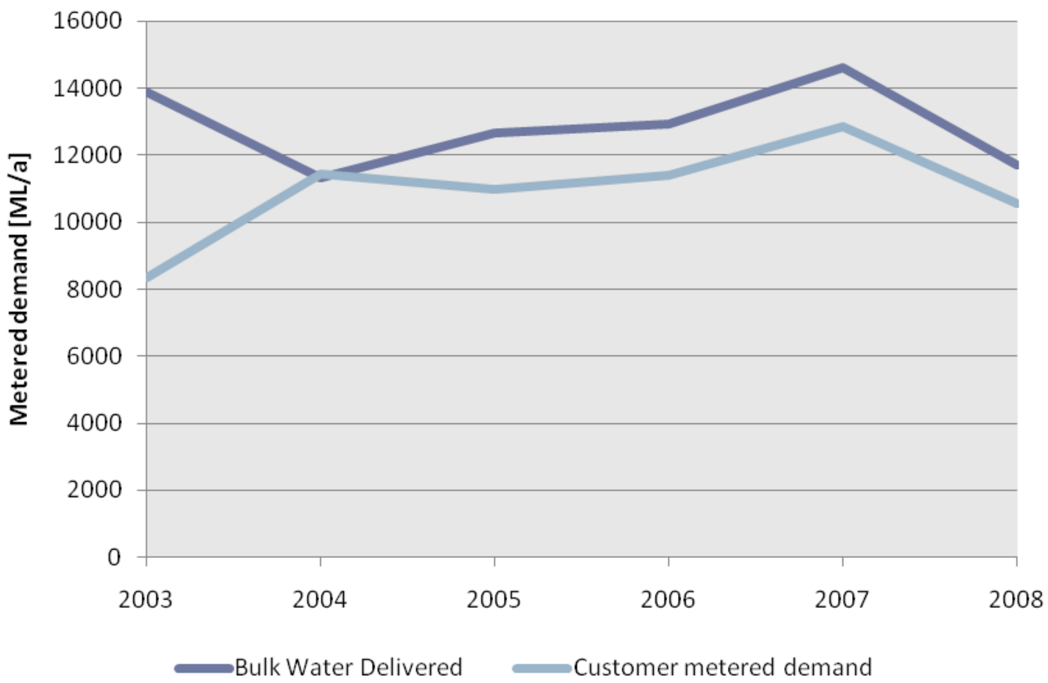


ISF recommends that the non-residential demand projections be adjusted as new information becomes available (for example, with the loss or addition of a major manufacturing industry).

Non-revenue water

The non-revenue water forecast in the model is based on the difference between the time series of metered bulk water production and customer metered consumption. The annual time series is shown in Figure 1.17.

Figure 1.17 Annual comparison of historical bulk water produced and customer metered demand (ML/a)



In the analysis, non-revenue water is defined as the difference between the bulk water produced and the customer metered demand. Based on the assumption that the share of non-revenue water will remain the same, the difference between these two time series (as a share of customer metered demand) was therefore applied as a factor to the total modelled demand from all other demand components to yield the forecast non-revenue water demand.

Noting the relatively low customer meter data in 2003–04, during this period RWCC implemented a program of metering improvement, which included installing meters on multiresidential dwellings. RWCC also experienced data export issues for that year due to a changeover in customer billing databases. Due to the apparent anomaly, the data presented in Figure 1.17 will be reviewed as part of RWCC's IWCM process.

Specifying the baselines

This stage involves the combination of the various baseline demand components and baseline system yield scenarios to form a baseline supply–demand forecast, shown in Figure 1.18. Note that no supply–demand gap is forecast to occur in the 'licensed allocation' yield scenario; however, in the assumed 'reduced allocation' scenario, a supply–demand gap is forecast to occur beyond 2017.

Figure 1.19 shows the components of the baseline demand forecast out to 2050. Figure 1.20 depicts the current (2010) baseline composition of potable demand for both the average annual and the peak day demand. The most obvious features of these figures are the dominance of residential irrigation as a share of total and peak day urban water demand, and the fact that future demand growth is being driven by growth in residential irrigation.

Figure 1.18 Baseline supply–demand balance for potable water in ‘licensed allocation’ and ‘reduced allocation’ scenarios (ML/a)

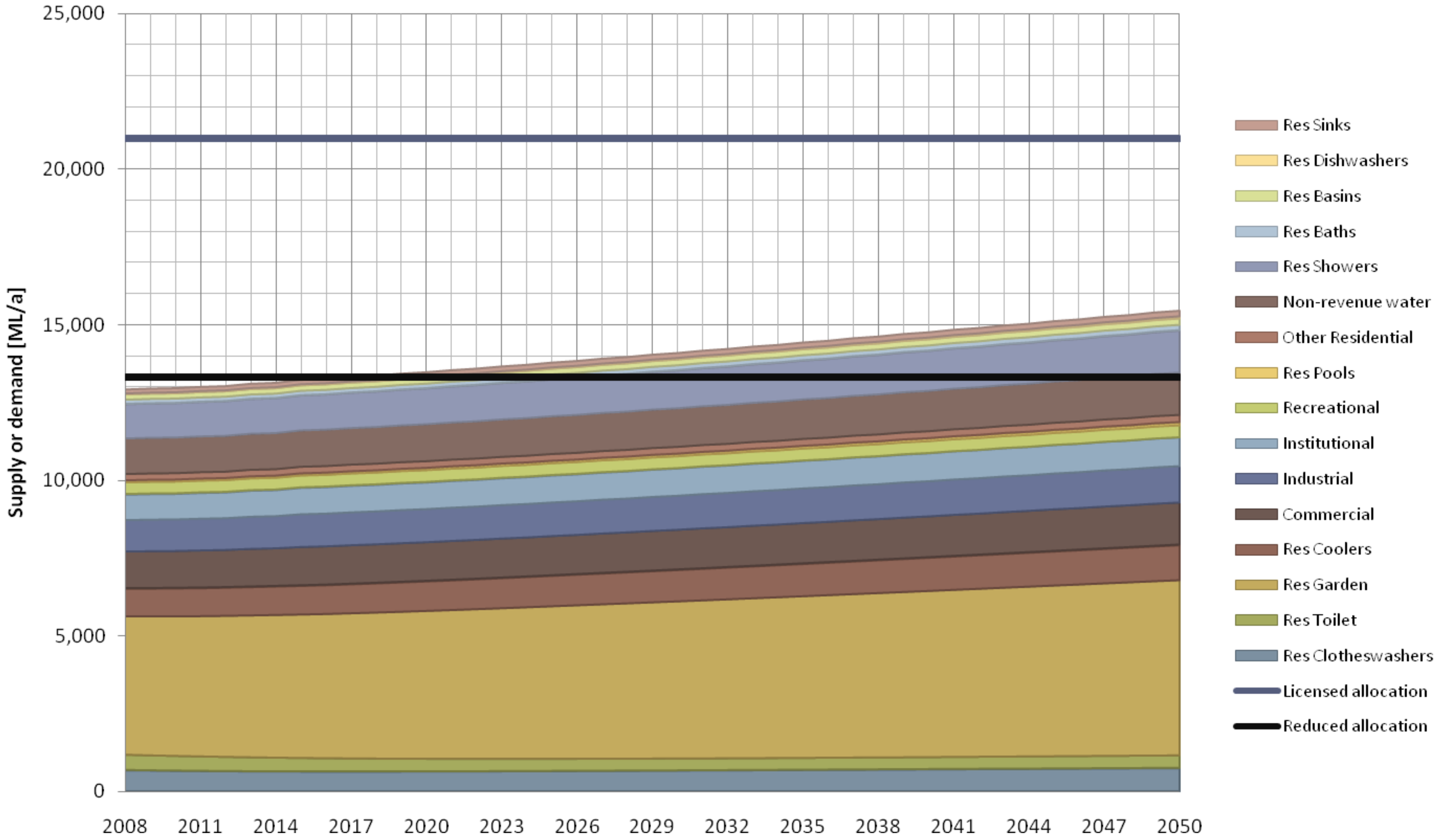


Figure 1.19 Baseline demand component forecast for potable water (ML/a)

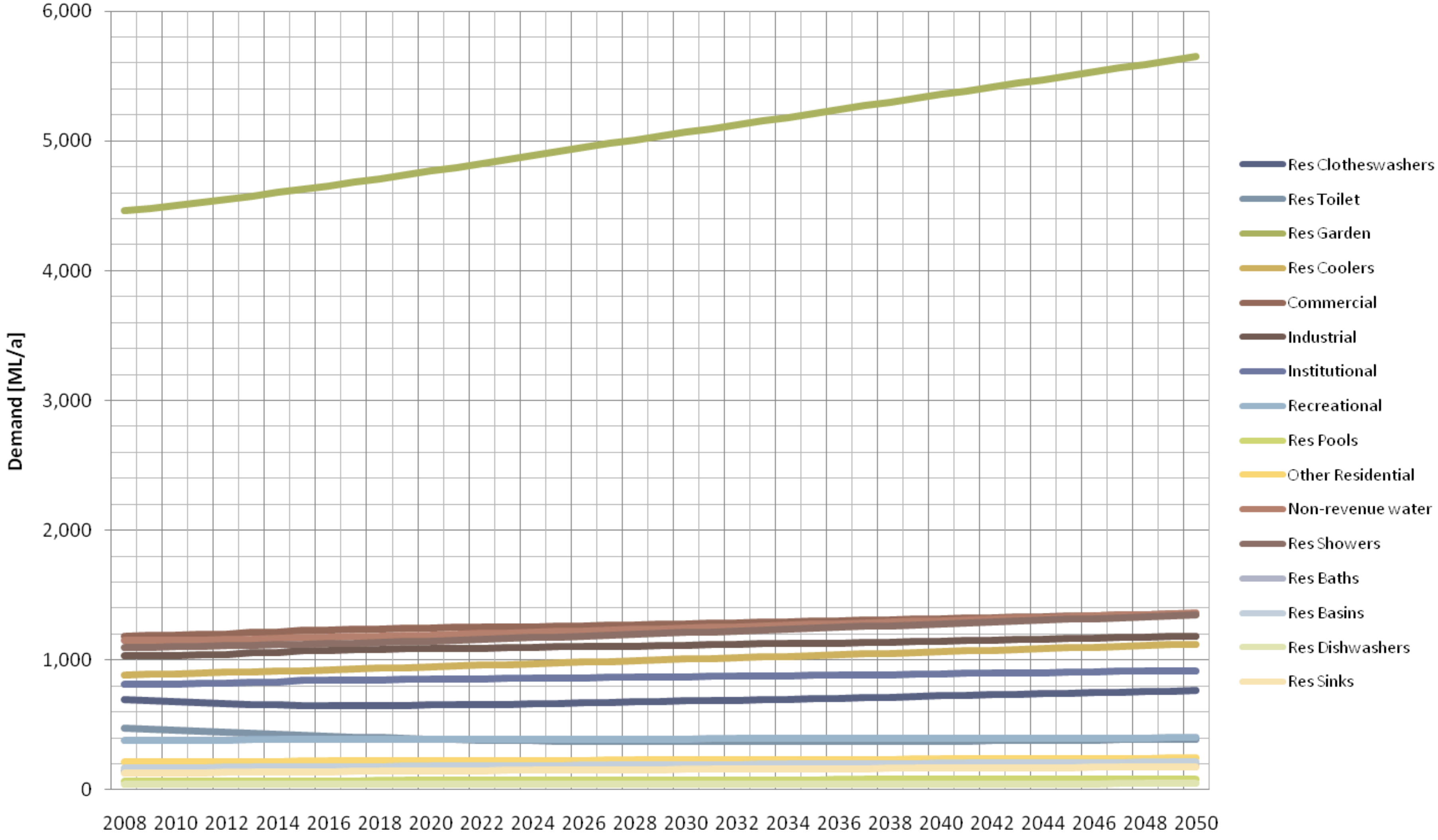
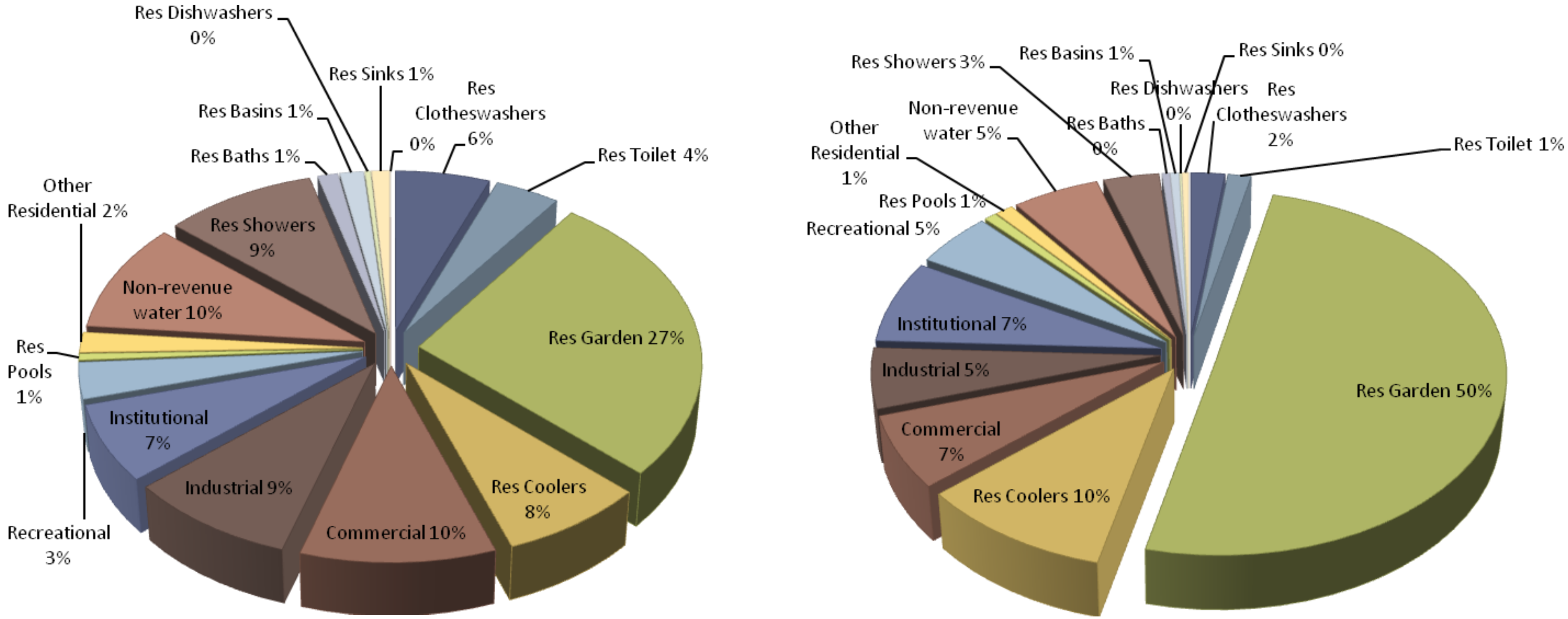


Figure 1.20 Baseline demand composition in 2010 for average annual demand (left) and peak day demand (right)



1.3.3 Developing the response

Identifying the options

Once the baseline supply–demand forecast has been established, the next stage of the analysis is to identify a suite of potential options and to assess them in relation to the objectives as outlined in Section 1.4.1. While the IRP assessment framework and iSDP model facilitate a comparison of supply-side and demand-side options, in this study only demand-side options were identified as having potential. This was because no immediate supply-side options were evident and there was no supply–demand gap projected under the 'licensed allocation' water availability scenario.

A broad suite of demand management and water conservation options was identified across the various sectors. Options were grouped into two alternative strategies: S1 ('tentative') and S2 ('more aggressive'). This was done in order to get a sense of the range of potential responses that might be implemented and to reflect the level of action that might be taken in the current situation with the licensed allocation and in a reduced allocation scenario. Some options were included in both strategies, but with differing assumptions concerning take-up rates and the corresponding effort required to drive take-up. The options are described in Table 1.1, with ticks used to indicate relative uptake. A double tick indicates that a more comprehensive version of the option has been included. The full assumptions used in modelling them can be found in Appendix 1B: Option details and assumptions.

Table 1.1 Potential demand management options included in the study

	Option	Description	Inclusion in strategy S1	Inclusion in strategy S2
1	Showerhead swap	Householders bring their old showerhead to a shopfront location and swap it for a new one, free of charge	✓✓	–
2	Residential retrofit	Plumber visit—replace showerheads, install tap flow regulators (kitchen and bathroom), toilet displacement device or cistern weight in single flush toilet; check for leaks and provide advice	–	✓✓
3	Toilets replacement	Complete toilet replacement (this option is currently being trialled in Wagga)	✓	✓✓
4	Clothes washer rebate	Rebate for replacing top loaders with 5-star front loaders.	✓✓	✓✓
5	Evaporative coolers	Maintenance visit and education campaign (turn them down, turn them off when not at home)	✓	✓✓
6	Residential nature strips	Rebate for relandscaping of nature strip (this option is currently being developed in Wagga)	✓	✓✓
7	Outdoor watering (DCP)	DCP banning irrigated lawns	–	✓✓
8	Rainwater tank rebate	5 kL tank retrofit for existing residential toilets, washing machines and outdoor uses (currently available)	–	✓✓
9	Permanent water conservation measures	No fixed sprinklers allowed between 10 a.m. and 5 p.m. All requested to reduce water consumption by 20% (this option has been adopted in Wagga)	✓✓	✓✓
10	Non-revenue	Leak detection and repair, pressure management program (from Sydney Water program)	✓✓	✓✓
11	Water audit—hotels	Water audit, install efficient fixtures and sensors and carry out air-conditioning maintenance. Proportion of total 49 hotels/motels	✓	✓✓
12	Water audit—schools	Monitoring, alarm systems for leaks, plus education. All 36 schools	✓✓	✓✓
13	Water audit—industrial customers	Water audits and modifications for five high water users	✓✓	✓✓
14	Commercial nature strips	Rebate for relandscaping of commercial properties	✓✓	✓✓

Assessing the alternatives

The results of the options assessment are shown in the graphs below. Figure 1.21 and Figure 1.22 depict the supply–demand forecasts for potable water, including the reduced demand associated with the S1 (tentative) and S2 (more aggressive) strategies, respectively.

Figure 1.23 and Figure 1.24 depict ‘cost curves’ of cumulative potable water yield due to a range of demand management options in 2020 against the cost of water for the S1 ‘tentative’ and S2 ‘more aggressive’ strategies, respectively. Both the water utility’s and the customer’s costs and avoided costs are included in order to approximate a whole-of-society cost. The costs include equipment, implementation, marketing, management and post-program evaluation. The avoided costs include operating costs (the water utility’s electricity and chemical costs in water supply and wastewater treatment, and the customer’s costs for heating water). Externality costs have not been included in this analysis. It was also not possible to included potentially avoided capital costs.

The y-axes in Figure 1.23 and Figure 1.24 therefore depict a net cost in dollars per kilolitre for each of the options. The x-axes show the cumulative yield available from the options, in terms of water supplied or potable demand avoided in the target year (in this case, 2030). Note that several options positioned to the left of the curve fall below the x-axis; they represent net avoided costs from the whole-of-society perspective.

Figure 1.25 and Figure 1.26 depict two further cost curves. These curves include only the direct costs of the option to the utility, in this case RWCC. The utility's avoided costs and forgone revenue are not included; nor are the customer's costs and avoided costs. Figure 1.22 and Figure 1.23 therefore provide an indication of the 'program cost' of the options and alternative strategies to the water utility.

Figure 1.21 Strategic supply–demand forecast for potable water subject to the ‘tentative’ S1 options (ML/a)

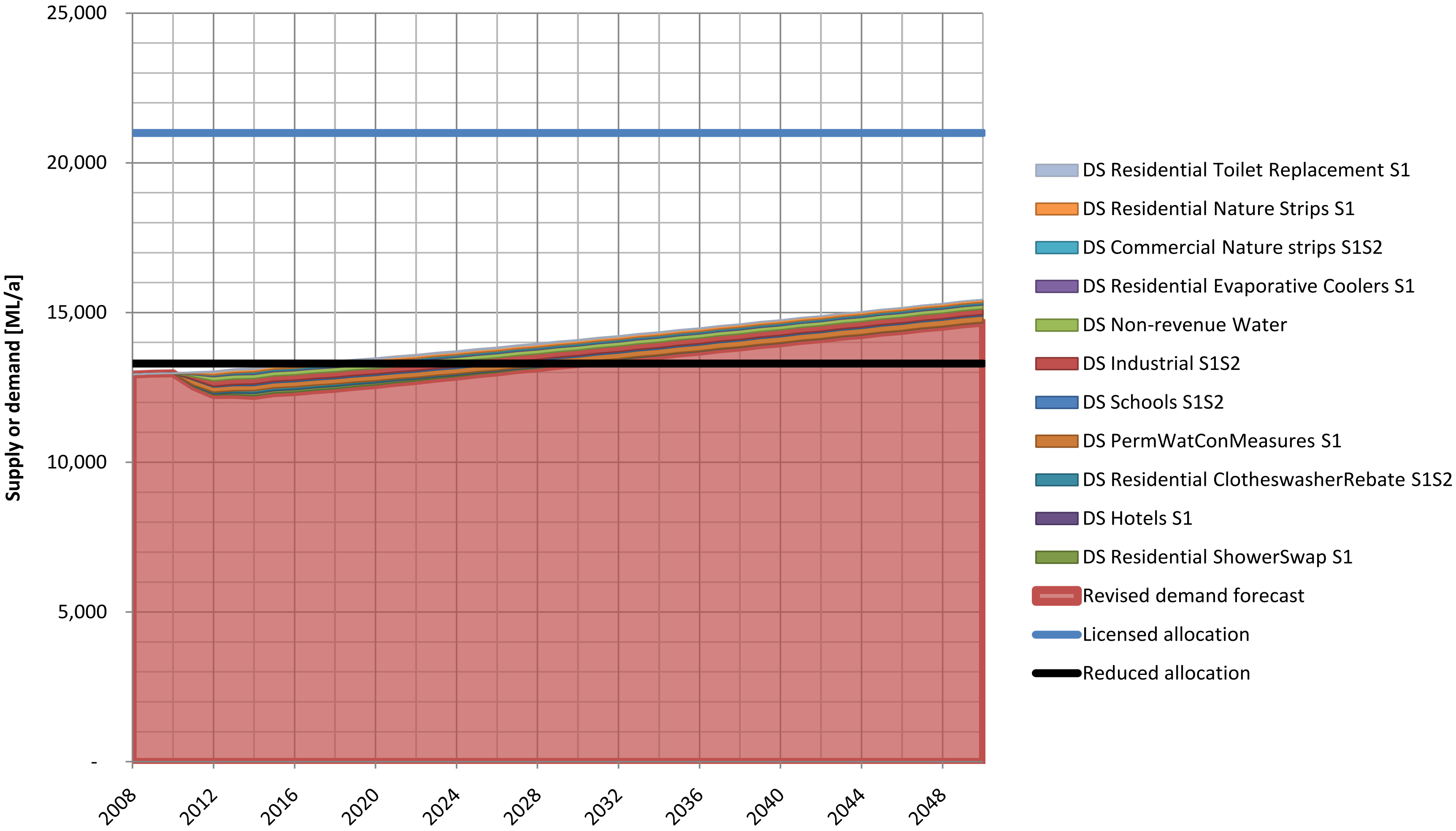


Figure 1.22 Strategic supply–demand forecast for potable water subject to the 'more aggressive' S2 options (ML/a)

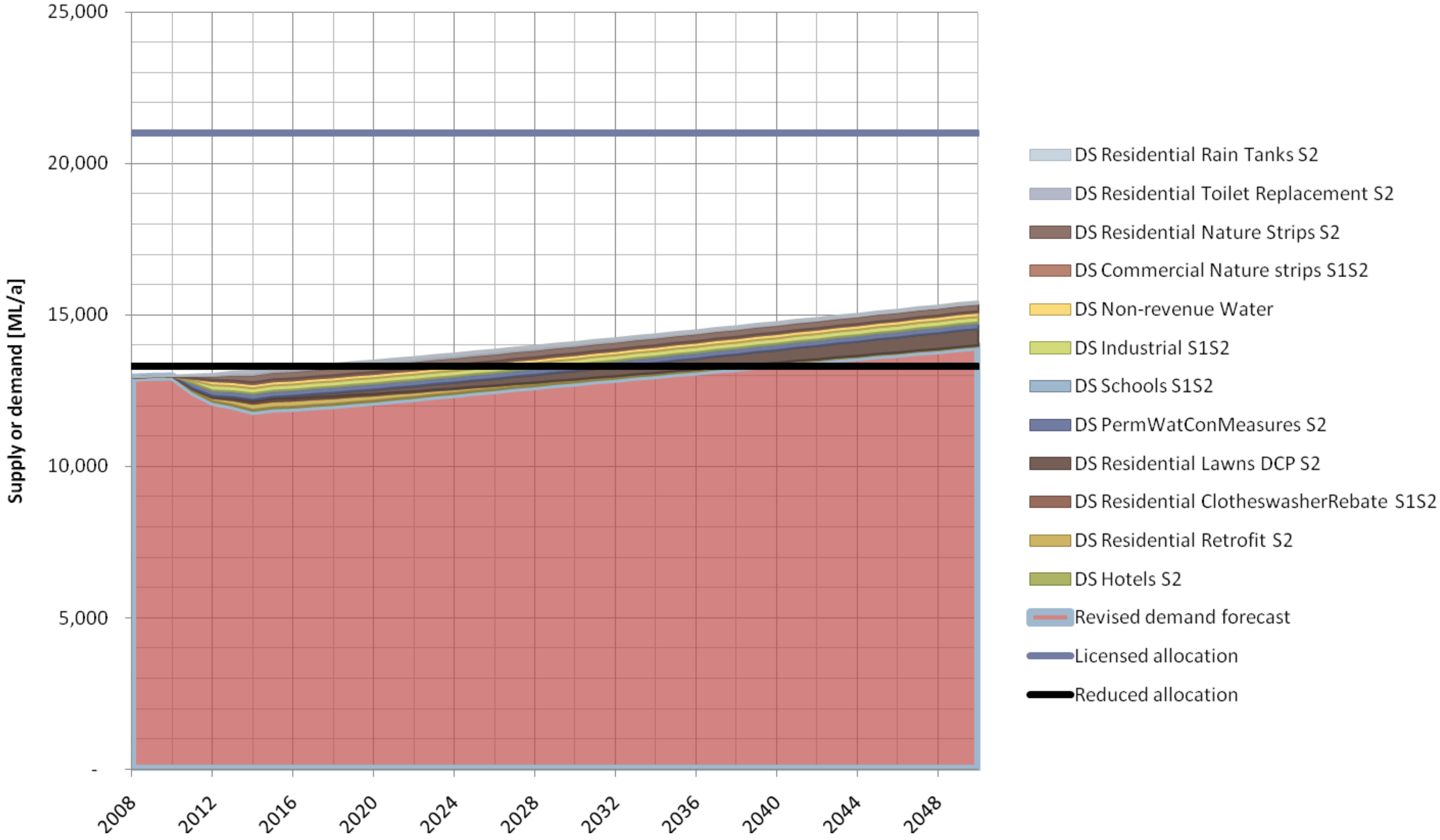


Figure 1.23 Societal net unit cost curve of cumulative potable water yield for the ‘tentative’ S1 options

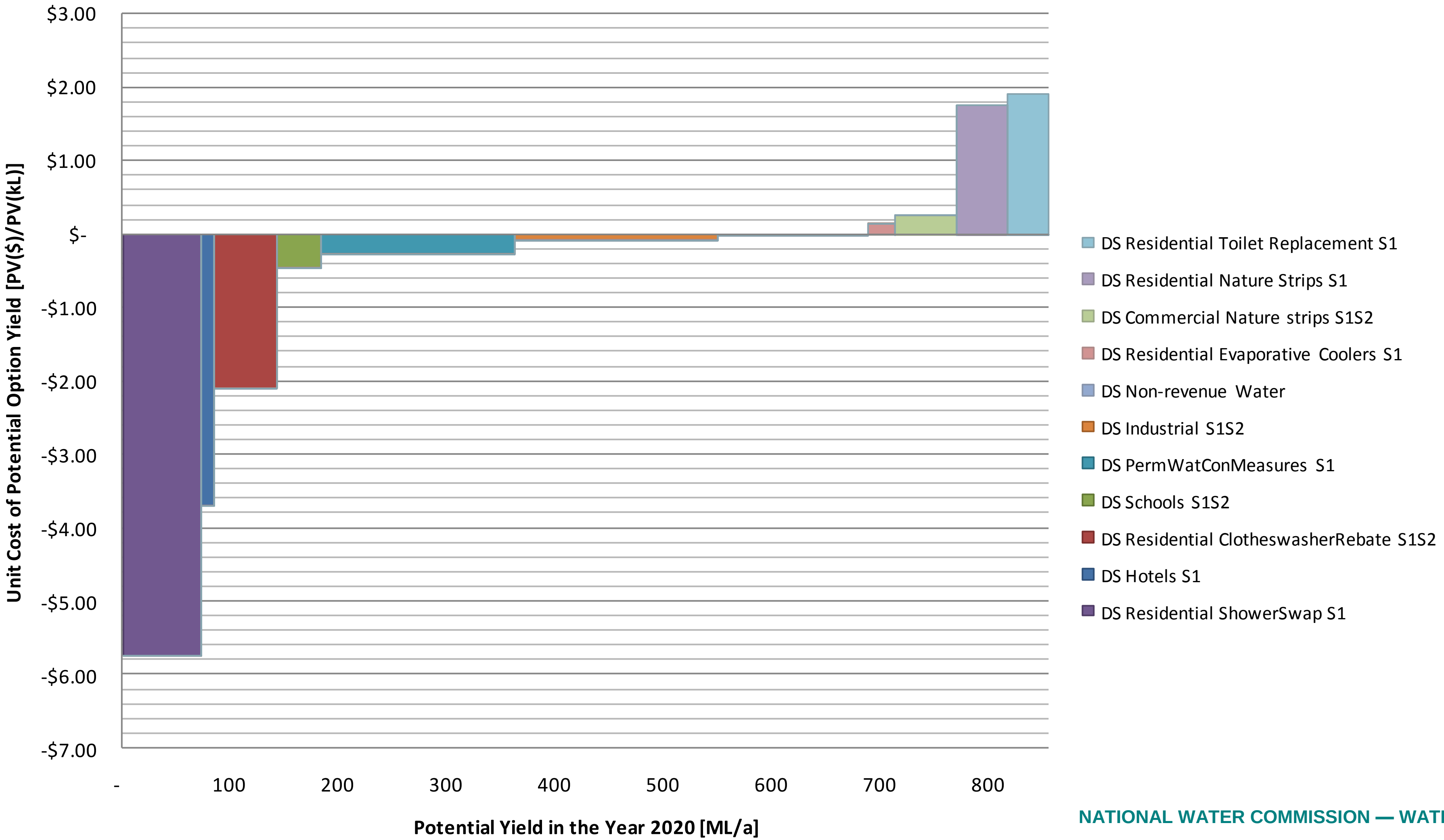


Figure 1.24 Societal net unit cost curve of cumulative potable water yield for the 'more aggressive' S2 options

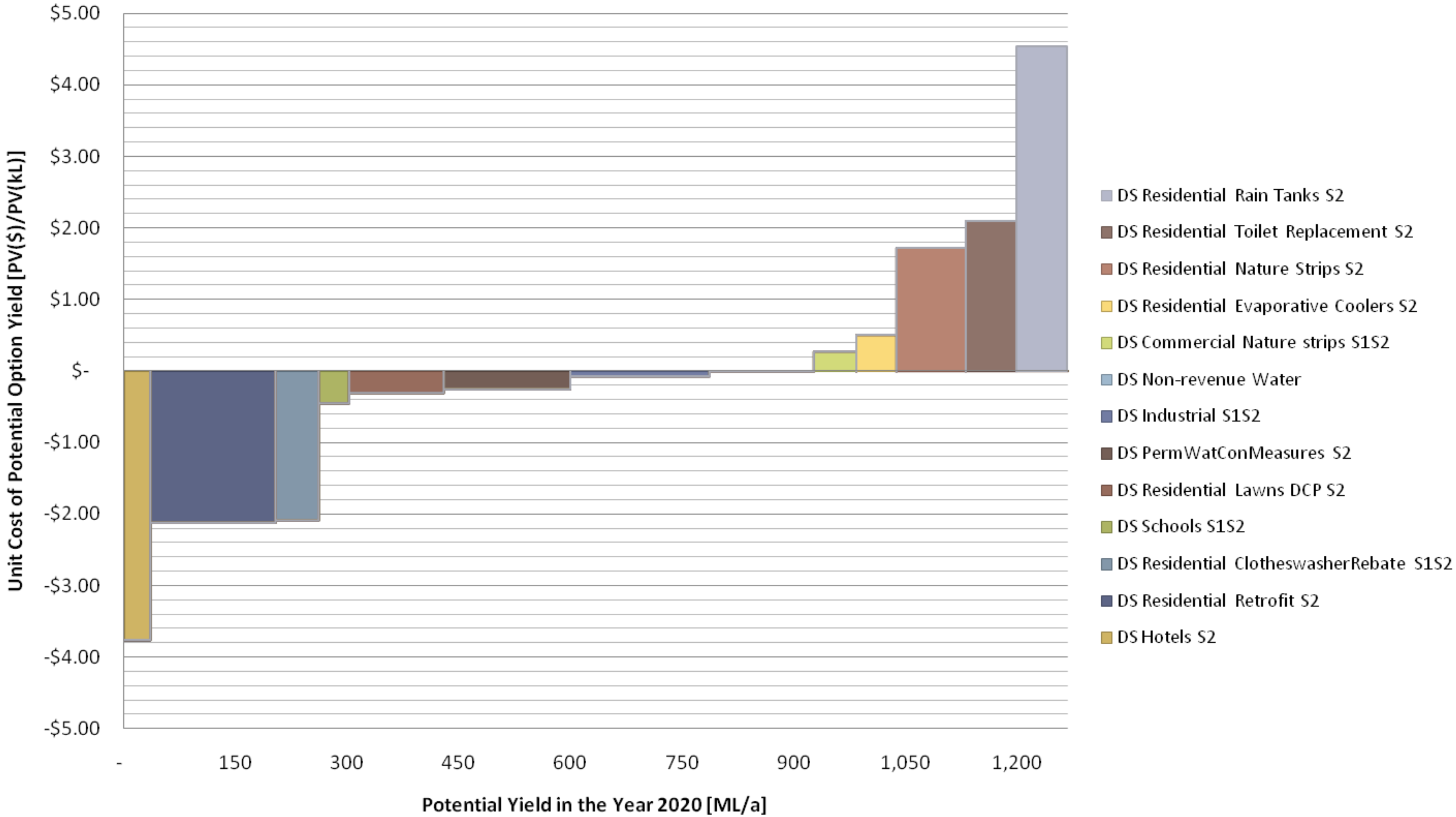


Figure 1.25 Utility ‘program’ unit cost curve of cumulative potable water yield for the ‘tentative’ S1 options

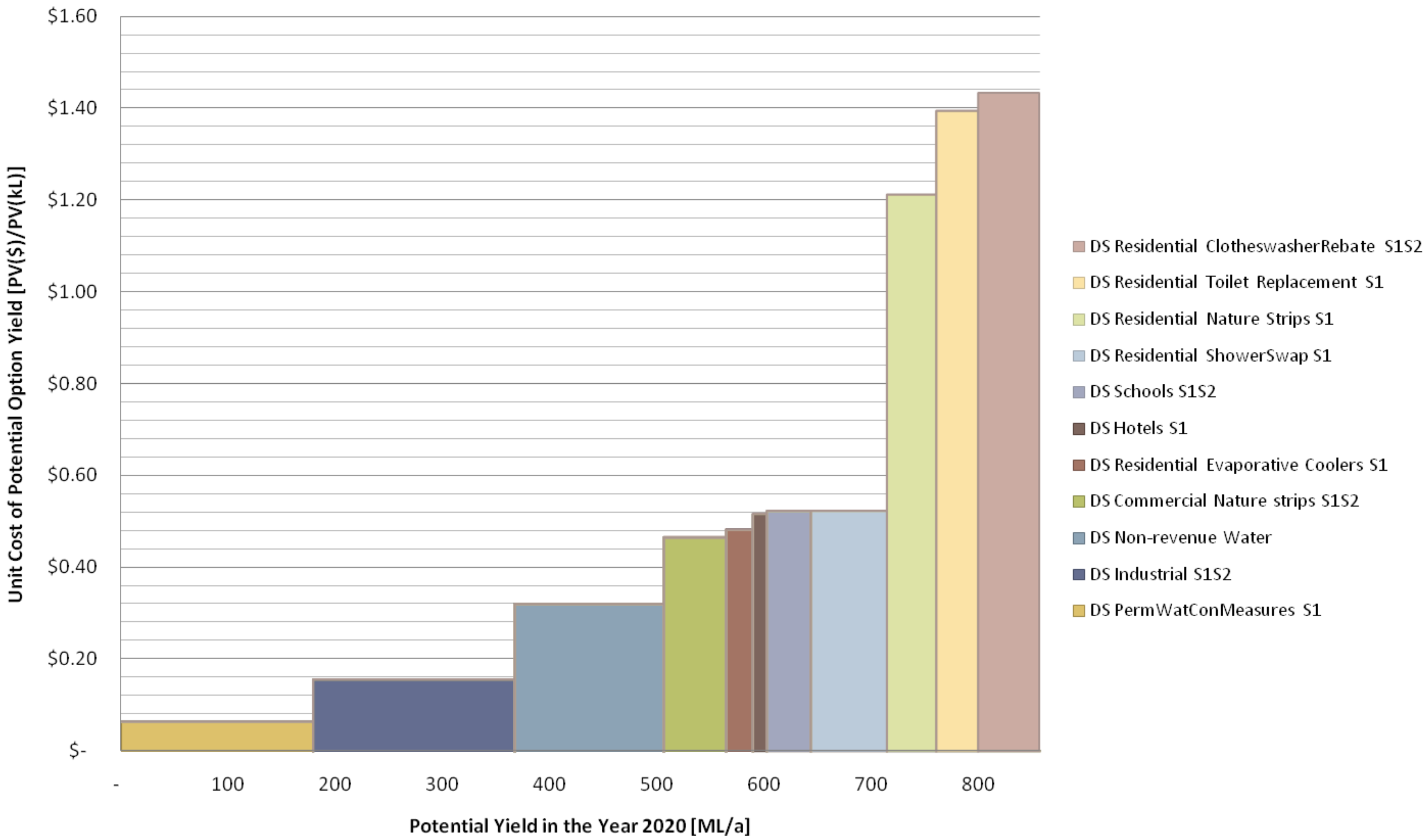


Figure 1.26 Utility ‘program’ unit cost curve of cumulative potable water yield for the ‘more aggressive’ S2 options

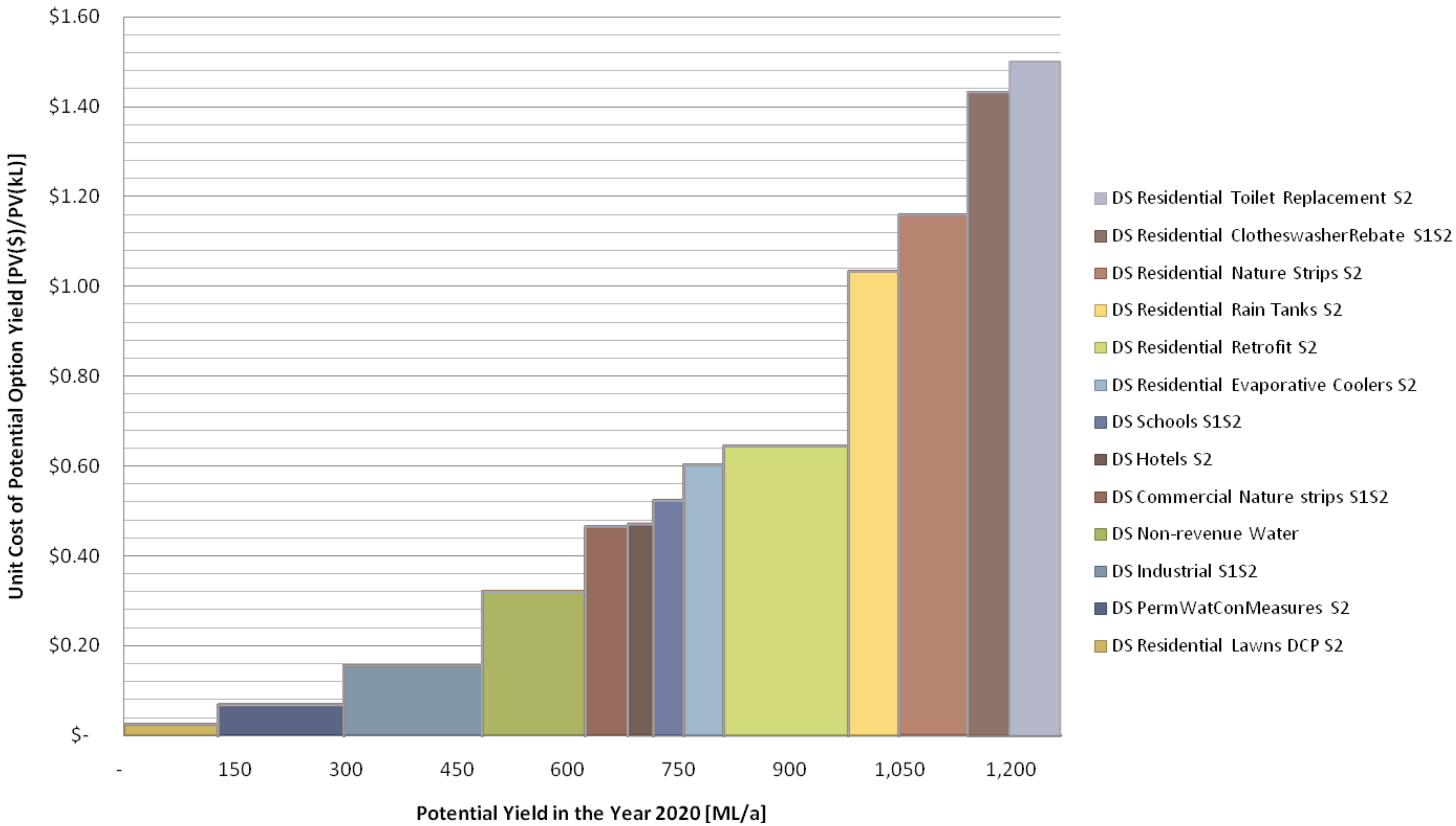


Figure 1.21 and Figure 1.22 show the potential demand reductions associated with the S1 (tentative) and S2 (more aggressive) strategies. In 2020, the S1 strategy could reduce demand by an estimated 900 ML/a, while S2 would give an estimated 1300 ML/a decrease. In 2050, these reductions would be 770 ML/a and 1470 ML/a, respectively. Neither strategy is likely to keep projected demand below the 'reduced allocation' scenario of 13 250 ML/a out to 2050. The demand forecasts show strategy S1 reaching the reduced supply allocation in 2028; S2 reaches it in 2038.

Figure 1.23 and Figure 1.24 show the net cost of potential options for the water utility and customers combined. If all costs could be included meaningfully in dollar terms, only those options with a zero or negative net cost should be implemented. The results show that the options with a zero or negative net cost were the residential retrofits or shower swap, the hotel program, the clothes washer rebates, the schools program, the residential lawn DCP, the permanent water conservation measure, the industrial water conservation program, and further action on non-revenue water.

However, the net societal costs in Figure 1.23 and Figure 1.24 did not include:

- the potential value of the surface water and groundwater for other uses
- the potential avoided cost of infrastructure upgrades, particularly those associated with peak demand reductions (estimated at $900/kL/day by RWCC)
- any social and environmental externalities (positive and negative), including in relation to the secondary objectives of reducing GHG emissions, in-town salinity and amenity.

Given the unaccounted-for benefits, particularly from initiatives that target peak day demand, it is likely that the commercial nature strip, the residential evaporative cooler and probably also the residential nature strip options would also all have a net benefit. For the commercial and residential nature strip option, there are also likely to be flow-on benefits in the form of culture change in which landscapers and householders change their practices and nurseries change their stock. Decisions about whether to implement those options need to be made in the light of consideration of those potential benefits.

Furthermore, future water availability for Wagga Wagga is a significant consideration, and the appropriate benchmark for investment in demand reductions needs to be determined in the context of decreasing water availability in the wider region and uncertainty about the impacts of climate change. The appropriate level of investment in urban water demand reduction is therefore a matter of judgment and a decision that requires stakeholder and community input (see below).

Figure 1.25 and Figure 1.26 show the utility's 'program' costs for the potential options. The costs include the marketing, implementation, administration and evaluation costs of the options to the utility and exclude any benefits from avoided pumping and treatment. These two cost curves give an indication of the direct cost of water to the utility from these options.

Table 1.2 shows the net societal cost and utility program cost of the two strategies adjusted so that those options that are unlikely to be cost-effective even with additional benefits (residential rainwater tank and toilet replacement) have been excluded. Greenhouse gas estimates of the two adjusted strategies are also shown.

Table 1.2 Net present value costs and estimated GHG reductions of alternative strategies

Strategy	*Societal net benefit (NPV)*	*Utility 'program' cost (NPV)*	*GHG emissions savings (tonnes CO_2-e)*
S1 adjusted	$4 850 449	$3 536 468	99 865
S2 adjusted	$4 830 395	$5 066 503	137 058

The results show that with residential rainwater tank and toilet replacement options removed both strategies have similar net benefits, estimated at about $4.8 million. From the utility's perspective, the 'more aggressive' adjusted strategy S2 would have a higher program cost (a net present value of $5 million, compared with $3.5 million for the more tentative adjusted S1 strategy. Unsurprisingly, the S2 strategy saves 37% more GHG emissions than S1.

When considering the figure in Table 1.2, it is important to realise that the societal net costs figures include the utility 'program' costs together with the utility's avoided costs and the customer's costs and avoided costs. Transfer payments between the utility and the customer associated with reduced water bills are cancelled out. Table 1.3 summaries the cost/avoided cost breakdowns for the two adjusted strategies. Appendix 1C: Options results—cost breakdown shows the full cost/avoided cost breakdowns for all the options.

Table 1.3 Summary cost breakdown for adjusted strategies

Strategy	*Customer costs*	*Customer benefits*	*Customer transfers*	*Utility costs*	*Utility benefits*	*Utility transfers*
S1 adjusted	$892 346	–$6 013 843	–$12 337 943	$3 536 468	–$3 265 421	$12 337 943
S2 adjusted	$1 543 098	–$6 994 806	–$17 320 947	$5 066 503	–$4 445 190	$17 320 947

Next steps: developing the strategy

As previously indicated, the scope of this case study is limited to the analytical steps of the IRP process for urban water. As described in the *Guide to demand management and integrated resource planning* (Turner et al. 2010), the analytical outputs of a supply–demand modelling and options assessment should be used to inform a decision-making process that includes stakeholder and community input.

The fact that urban water planning should include stakeholder and community input is also embedded in the national urban water planning principles released by the Council of Australian Governments in 2009. Input is important in relation to both the supply and demand options that are considered and implemented, and in relation to the expected 'levels of service' and the management of uncertainties about future climate.

Based on analysis and stakeholder and community input, the output of urban water planning should then be the selection of a preferred group of options, together with a comprehensive strategy for their implementation, monitoring and review. For further guidance on the broader process of IRP and its relevance to the Council of Australian Governments principles, refer to Turner et al. (2010).

The demand analyses and options developed in this study were included in stakeholder workshops as part of the IWCM planning process being conducted by RWCC.

1.4 Discussion

1.4.1 IRP for coastal and inland cities

In the past, the iSDP model has primarily been used to assess water supply–demand planning options for large Australian coastal cities. Those cities are invariably shown to have a water supply–demand gap over the longer term. However, this case study represented a different scenario, as Wagga Wagga is an inland city with no current supply–demand gap and with a different set of water management issues from most Australian coastal cities.

In Wagga Wagga, rainfall is lower and evaporation is higher than on the coast. The town water supply is sourced both from groundwater and directly from a river. In Australian coastal cities, water is sourced from surface waters in dams or more recently from desalination plants. The other major differences are that the riverine water supply is dependent on a state government-specified water allocation rather than a dam, and that wastewater discharged from the town is returned to the river. There is also an interaction between the river and the groundwater aquifer.

The differences in water cycle issues between coastal and inland cities are outlined in Table 1.4. These differences were highlighted early in the process, as there were questions about the suitability of the IRP process and iSDP model for use with an inland city. Understanding these differences helped to inform the approach and the selection of options. Adjustments were made to parts of the model to adapt to the differences; however, overall the process and model were found to be readily applicable to an inland city.

Table 1.4 Differences in water cycle issues between coastal cities and inland cities

Water system element	*Coastal city*	*Inland city*
Water supply	Usually from dams or desalination	Usually from groundwater and/or rivers
Supply dependent upon	Dam yield and capacity of potential supply alternatives	Available yield from groundwater and river allocations
Critical demand	Considered on a seasonal and annual basis	Considered in terms of 'peak day', as well as on an annual basis
Wastewater discharge	To the ocean	To a river
Wastewater recycling	Wastewater recycling reduces potable demand	Wastewater recycling reduces potable demand, but also discharge that would have been reused downstream
Rainwater	Becoming more common for non-potable end-uses	Common in areas of high rainfall for potable and non-potable end-uses, but less valuable in drier regions
Stormwater	Captured for beneficial reuse in some areas. Allowing it to drain to the ocean is seen to be a 'waste'	Provides flow for rivers. This is seen as a benefit to either the environment or the next downstream town
Nutrient discharge	Less concern when nutrients are discharged to ocean. Greater concern where nutrients are discharged to an estuary or bay	High concern, as nutrients can be detrimental to downstream areas
Salinity—both land and water	Only an issue where groundwater is used (i.e. Perth)	A common issue for inland cities

One of the key differences is that, without a dam, the supply infrastructure in Wagga Wagga is designed mainly on a peak day demand. Summer peak day savings therefore become an important driver for capital costs and demand management resulting in reduced peak days—a financial benefit. Estimating these potential avoided costs requires network modelling to determine how the projected reduction in demand reduces infrastructure needs. The IRP process does not usually include such analysis (see the comparison with the IWCM process for Wagga, below).

Another challenge for adapting the urban water IRP process to Wagga Wagga was the different interpretation of baseline system yield. The allocation sets a ceiling on water use, but it is subject to allocation decisions and can change during drought. This potential to change was dealt with in this analysis by preparing two different yield scenarios: one representing the current situation (licensed allocation) and the other representing a future in which allocations are significantly reduced (reduced allocation).

Wagga Wagga is a relatively small water user in the context of the Murrumbidgee and larger Murray–Darling river systems. The Murray–Darling Basin Plan addresses critical human needs and gives them a top priority. Therefore, any assessment of the cost-effectiveness of demand management options for the city is partial, given the considerable potential yield reductions that are likely to be possible in irrigated agriculture in the system. Furthermore, given that all indoor demand flows are returned to the river system in the form of treated wastewater, the benefits to river flow of indoor demand management may be considered lessened. This is not necessarily the case for groundwater.

However, the protection of critical human needs is unlikely to extend to residential outdoor use. This, combined with Wagga's rising saline watertable, led to an emphasis in the case study on the analysis of outdoor demand and its efficiency potential. In response, the case study involved a novel application of the soil moisture balance methodology to the urban situation. The results revealed that baseline irrigation demand was not excessively higher than the water requirements of a European-style turf and garden landscape subject to the prevailing climatic conditions. This suggests that options that aim to change garden types are more likely to be successful than education to alter watering behaviours.

1.4.2 Data requirements and the level of analysis

The IRP process can be complex, and gathering data of sufficient quality is time consuming. Such a process is obviously justified when there is a supply–demand gap and a city is considering expensive new supply augmentations, but is it over-detailed for a city like Wagga Wagga.

The fact that Wagga Wagga does not currently have a supply–demand gap means that interventions are not immediately required. One perspective could then be that the level of detail required by the IRP process is not warranted.

However, the analysis has shown that a suite of demand management options can be implemented with a net benefit to the community as a whole. Furthermore, Wagga Wagga is within a region where significant decreases in water availability are occurring and are expected to continue because of the impacts of climate change. In this context, understanding the demand for water within the city and what might be able to done to reduce demand appears to be warranted.

1.4.3 Comparing the IRP and IWCM approaches

RWCC commissioned HydroScience Consulting (HSC) to help it conduct an IWCM planning process, including the required analysis. At the point of finalising that study, HSC and RWCC were at a similar stage to this report. The initial analysis of water supply, water demand forecasts and the assessment of alternative demand management and water conservation strategies had all been completed. With RWCC conducting an IWCM process concurrently alongside this study, there is an opportunity to compare and contrast the two approaches to urban water supply–demand planning.

Key areas of similarity between the approaches include:

- an initial analysis of bulk and customer demand data
- the development of demand and supply forecasts
- the assessment of demand-side (and supply-side) options
- the consideration of groups of options (called ‘portfolios’ or ‘alternative strategies’ in IRP and ‘scenarios’ in IWCM).

Areas of difference include:

- the focus on initial demand analysis and subsequent forecasting in the IRP process
- the detail of the stock and end-use based forecasting models in the IRP process
- the role of individual option costing and the importance placed on least-cost service provision in the IRP process
- the focus on peak day demand in IWCM
- the role of the New South Wales Government in IWCM.

The analysis of water demand in this study focused on various sectors and subsectors (commercial, high water using industrial, schools etc.) in order to understand water demand and also to aid in the design of demand management options. In contrast, the demand analysis by HSC focused on service areas and particular infrastructure constraints (pipes, filtration or treatment plant). The HSC demand analysis and forecasting also had a strong focus on peak day demand. As RWCC extracts water from a river rather than a dam, its supply infrastructure is designed on peak day criteria and so peak day savings become an important driver for avoided costs. This study included some peak demand analysis but had a focus on average day demand. This could be seen as a weakness in the IRP approach as applied. A combination of area-based peak demand analysis and sectoral and end-use based demand analysis could be explored in future studies. This is particularly the case for inland regions like Wagga Wagga, where very high peak day demands are a driver for infrastructure spending.

For its analysis, HSC applied three models developed by the NSW Office of Water: the water demand trend tracking and climate correction model; the demand-side management decision support system (DSM DSS); and the rainwater tank assessment model. After the initial demand analysis, the forecasting and options assessment in this study were conducted within the iSDP model. The iSDP model incorporates detailed stock models, which can be linked to the demand management options that are developed. This allows for forecasts of future demand that account for natural changes towards more efficient appliance and plumbing fixture stock over time, and savings estimates to account for those changes. The iSDP model incorporates a rainwater tank model and allows the user to build their own options based on templates. The DSM DSS utilises a less detailed end-use and stock modelling approach and has a set choice of options.

In general, the IRP analysis is more strongly tied than IWCM to the principle of least-cost service provision. In the HSC study for RWCC, the potential impact of demand-side options on future demand is forecast but, with the exception of rainwater tanks, the cost-effectiveness of individual options is not evaluated. The DSM DSS does provide a benefit–cost ratio for alternative strategies, but a unit cost figure in $/kL for each of the options is not provided. The value of this individual option costing in urban water planning can be debated, but the use of levelised unit costs to build up alternative strategies or portfolios of options is central to the IRP approach.

The final area of difference is the role of the New South Wales Government. IWCM is a process designed for local water utilities in NSW to help them better manage their water supplies and thereby benefit their communities and the environment (NOW 2010). It is a component of the NSW Government’s best practice management of water supply and sewage guidelines and it is a prerequisite for some classes of funding applications by local water utilities to the government. The IRP process and tools are provided for the use of water utilities across Australia, but are not a currently a requirement for urban water planning in any state. Significantly, in consultation with the NSW Office of Water, analysis conducted with IRP tools such as the iSDP model can be used for IWCM planning processes.

From RWCC’s perspective, IRP and IWCM complemented each other. IWCM focused on growth and supply limits, while IRP focused on end use, demand analysis and demand management. The combination provides a strong platform for water planning for Wagga Wagga (Finlayson 2010).

1.5 Conclusions

1.5.1 Recommendations for the IRP process

During the IRP process for Wagga Wagga, a range of recommendations arose that are generally applicable to water utilities about to undertake the process:

- The IRP process works particularly well for water utilities facing a supply–demand gap, as the detailed nature of the process ensures that a wide range of water saving options are investigated and prioritised in order of cost-effectiveness.
- In cities where yield is defined as an allocation (that is subject to regulatory changes), it is important to test a range of plausible future scenarios (for example, in which the allocation is decreased due to reduced regional water availability).
- It is worth investing time to ensure that bulk meter data is fairly accurate, so that the results of the analysis are meaningful. Poor input data quality diminishes the usefulness of the analysis.
- Peak day demand should be included as a focus of the IRP process / iSDP model for inland cities in the future.

- For areas with water availability constraints, it is worth undertaking some simple research to confirm specific local end-use assumptions. For example, shower flow rates are both highly sensitive and regionally specific (they are typically dependent on local water pressure). Evaporative cooler use and settings are also highly specific to local climatic conditions.
- Preprocessing of non-residential data (for example, analysing per property consumption for each sector) provides valuable insights into the relative consumption of each sector, trends in consumption and areas where there may be demand management potential. This helps to more accurately forecast growth and also to identify appropriate and targeted options for demand management.
- Non-residential demand projections should be adjusted as new information becomes available. The loss or addition of a major industry can significantly affect the forecast.
- Options should be assessed on the basis of whole-of-society costs, and only those options with a net benefit (or negative net cost) should be implemented. However, in most circumstances, estimating all the costs and avoided costs to all parties is unlikely to be possible. It is therefore important to detail which costs and benefits could be included in the analysis and which could not. This then allows decision-makers to make an informed judgment.

1.5.2 Recommendations for Wagga Wagga

The main drivers for undertaking the IRP process in Wagga Wagga were the possibility of changes to town water allocations in the context of constrained water availability and climate change, continuing urban growth, salinity in urban groundwater and soils, a stressed aquifer system and the general need for all organisations to look at potential GHG emissions reductions. These drivers lead to an analysis of a range of demand management and water conservation options with a focus on reducing outdoor watering.

The results showed that, of the 14 options considered, only two (residential rainwater tanks and residential toilet replacements) could not be recommended because of their high net costs. A suite of options could be recommended for stakeholder consideration based on their negative or very low net costs. These were residential retrofits or shower swaps, the hotel program, the clothes washer rebates, the permanent water conservation measures, a residential lawn DCP, further action on non-revenue water, schools programs and industrial programs.

The analysis could not inform a recommendation about commercial and residential nature strip options. However, stakeholders should consider that these relatively high net cost options target outdoor demand and peak day demand. These options help reduce soil salinity problems and will avoid costs related to infrastructure upgrades that are associated with peak day demands.

The appropriate benchmark for investment in urban water demand reductions also needs to be considered in the light of future water availability in the wider region.

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Appendix 1A: Baseline assumptions

Baseline component	*Description*	*Notes*	*Assumptions*
Res Clotheswashers	Baseline component for the clothes-washing machines in residential dwellings	Based on product of projected residential household numbers, projected clothes washer penetration, projected usage frequency, and mean consumption.	Lifetime of appliance for stock modelling is assumed to be 10 years; based on sales data and information from manufacturers (EES 2008). Note that the appliance lifetime is assumed to be independent of time. Standard deviation used in stock modelling is assumed to be 0.5; based on sales data and information from manufacturers (ECU 1995 Decade 2nd year report). Note that the appliance lifetime standard deviation is assumed to be independent of time. Phosphorus consumed by end use as grams per activity; based on measurements of phosphorus load of common detergents under recommended dosage (Patterson 2007), weighted using national detergent market share data (ACN 2007) Total annual sales of appliance, including those for new dwellings and replacements within existing dwellings, as units per annum; based on simulated stock decay in cohort stock model (and therefore replacement), ownership share and projected number of dwellings. Mean consumption of water as litres per use; based on linear decay model with asymptote assumed at 115 L/use and 70 L/use for top-loaders and front-loaders, respectively. The historical consumption data is based on the figures presented in Greening White Goods study for 1993–2005 period (EES 2005). Proportion of available properties with operational appliances as %; based on smoothed state-wide data (ABS 2008) and assumed market saturation (i.e. constant ownership) thereafter. Proportion of end-use potable water demand that is wastewater is assumed to be 1; assumes all input water flows diverted to wastewater. Mean frequency of appliance use as activities per household per year; based upon a linear interpolation of per capita usage study undertaken for Melbourne (Roberts 2005) multiplied by the occupancy ratio for single residential dwellings. Mean frequency of appliance use as activities per household per year; based upon a linear interpolation of per capita usage study undertaken for Melbourne (Roberts 2005) multiplied by the occupancy ratio for multiresidential dwellings. Total number of appliances currently operational in the region as appliances; based on modelled penetration multiplied by total number of residential dwellings.

Baseline component	*Description*	*Notes*	*Assumptions*
Res Toilet	Baseline component for toilet flushing in residential dwellings	Based on product of projected residential population, mean home toilet flushing frequency, and mean toilet flush volumes.	Lifetime of appliance for stock modelling is assumed to be 25.7573139129773 years; calibrated to observed decay of single-flush toilet stock. Standard deviation used in stock modelling is assumed to be 0.333562629587071; calibrated to observed decay of single-flush toilet stock in ABS Environmental Issues Survey (2005). Mean leakage rate of installed appliances is assumed to be 1.09575 kilolitres per appliance per annum; based upon ISF evaluation. Phosphorus consumed by end use is assumed to be 1.66562 grams per activity; based upon national dietary protein intake of 113 grams per day (FAO 2010) apportioned to phosphorus as 1.1% of dietary protein, of which 45% is faecal and 55% urine (Jönsson & Vinnerås 2003). Nitrogen consumed per person is assumed to be 14.69 kilograms per annum; based upon national dietary protein intake data (FAO 2007) apportioned to nitrogen as 13% of dietary protein, of which 15% is faeces and 85% is urine (Jönsson & Vinnerås 2003). Mean frequency of appliance usage is assumed to be 3.8 uses per person per day; based upon end-use measurement study in Melbourne (Roberts 2005). Mean number of appliances per household as appliances per household; based upon two domestic water-use studies in Perth over an 18-year period (MWA 1985, Loh & Coghlin 2003) interpolated linearly and forecast to remain at constant level into the future. Mean consumption of water as litres per use; based on flush volumes from end-use measurement study in Melbourne (Roberts 2005), full flush to half flush frequency ratios inferred from AC Nielsen study, and projected changes in appliance stock mix over time. Projected stock changes based on lognormal stock model with constant appliance lifetime and standard deviation. Proportion of end-use potable water demand that is hot water; assumes toilets consume cold water only. Proportion of end-use potable water demand that is wastewater is assumed to be 1; assumes all input water flows diverted to wastewater.
Res Pools	Baseline component for pools in residential dwellings	Based on product of projected residential household numbers, penetration of pools in residential households, and mean pool water consumption. Mean pool water consumption based on water balance model.	Mean water consumed by the existing mix of appliances is assumed to be 25.9398326565206 kilolitres per property per year; based on water balance model. Proportion of available properties with operational appliances as %; based on household ownership data (ABS 2007). There is no apparent trend in the empirical data; therefore, the precast swimming pool ownership is assumed constant to first data point. Intermediate data points are interpolated linearly, and forecast ownership is assumed constant from last data point.

Baseline component	*Description*	*Notes*	*Assumptions*
Res Coolers	Baseline component for evaporative coolers in residential dwellings	Based upon product of projected residential household numbers, appliance penetration, frequency of use, duration of use, and consumption as a mean flow rate.	Mean frequency of appliance usage is assumed to be 0.266912366912367 uses per person per day; based on the number of days local maximum temperature exceeds 25 degrees Celsius, supported by residential end-use measurement study of Melbourne (Roberts 2005) finding this to be a key threshold. Proportion of available properties with operational appliances as %; based on telephone conversations with suppliers in the region, pending more detailed local surveys. Note that state-wide ownership data (ABS 2005) was deemed an insufficient characterisation of the service area. Mean duration of appliance operation per use is assumed to be 360 minutes; based on appliance stock and usage survey (Roberts 2004), which found duration per use lower than for air-conditioners etc. Harvey report found average duration of 4.5 hours. ISF phone surveys of suppliers in Canberra and Wagga suggest ~6 hours. Mean flow rate during appliance operation as litres per minute; based on phone interviews with several installation retailers suggesting a mean flow rate of ~120 L/hr for continuous bleed coolers (×133% to account for poor installation) and ~48 L/hr for auto dump coolers, subject to high estimate uncertainty.
Res Garden	Baseline component for lawns and gardens in residential dwellings	Based on product of projected residential household numbers, mean lawn and garden areas, and mean lawn and garden water intensity. Lawn and garden water intensity per unit area based on daily soil moisture balance model calibrated to ensure that total CMD volumes are equal over the calibration period.	Characteristic soil type for the service area is assumed to be 2 (1 = Sand, 2 = Loamy sand, 3 = Sandy loam, 4 = Loam, 5 = Sandy clay loam, 6 = Loam clay, 7 = Clays); based on local soil maps. Mean lawn area for detached residential dwellings is assumed to be 210 square metres; based on review of aerial photography for the service area using an indicative sample of households. Mean garden area for detached residential dwellings is assumed to be 50 square metres; based on review of aerial photography for the service area using an indicative sample of households. Mean lawn area for non-detached residential dwellings is assumed to be 60 square metres; based on review of aerial photography for the service area using an indicative sample of households. Mean garden area for non-detached residential dwellings as square meters; based on review of aerial photography for the service area using an indicative sample of households. Factor by which households in detached residential dwellings overwater their gardens compared to moderate lawn performance is assumed to be 1.37868840474506; based on soil moisture balance calibrated to binned customer meter data. Factor by which households in non-detached residential dwellings overwater their gardens compared to moderate lawn performance is assumed to be 1.89027893933127; based on soil moisture balance calibrated to binned customer meter data.

Baseline component	*Description*	*Notes*	*Assumptions*
Non-revenue water	Baseline component describing non-revenue water, including real losses and apparent losses		Real losses per service connection that are deemed unavoidable are assumed to be 62.5 kL per connection; based on WSAA standard. Mean number of service connections per property is assumed to be 0.899; based on rough estimate—no data acquired. Proportion of total water delivered defined as non-revenue water is assumed to be 9.91759807040403E-02; based on observed difference between bulk water delivered and customer meter demand; assumed to remain constant as a proportion of bulk water delivered. Proportion of total water delivered defined as unbilled metered demand; no data available. Proportion of total water delivered defined as unbilled unmetered demand; no data available. Proportion of total water delivered defined as unauthorised consumption; no data available. Proportion of total water delivered attributed to customer metering inaccuracies; no data available.
Commercial	Baseline component for the commercial sector disaggregated into average customers and water-intensive customers	Average customer demand forecast based on projected demand per customer (assumed equal to mean historical demand per customer) multiplied by the projected number of customers by subsector (proportionally projected with population). Water-intensive user demand forecast based on case-by-case projection of future demand (i.e. proportionally projected with population or constant).	Demand associated with average users in the commercial sector as ML/a; demand for average users assumed to be represented by an average consumption value (ML/location/a) multiplied by the forecast number of average user lots in a given future year. Demand associated with high water users in the commercial sector as ML/a; demand for high users assumed to be represented by an average consumption rate for each user (ML/a) averaged over either the 2004–2006 historical period, or just using the historical 2006 value. The choice of averaging period depends on the test of the ratio of the standard deviation to mean of the last three year's consumption rates. If that ratio <0.5, then the period 2004–2006 is used, whereas if the ratio is >=0.5 just the 2006 value is used. This is to account for high variance that may be experienced over the 2004–2006 period. High users are forecast based on either a scaled constant (between 0 and 5), or pegged to population growth to represent the emergent demand associated with future high water users of that land-use type.

Baseline component	*Description*	*Notes*	*Assumptions*
Industrial	Baseline component for the industrial sector disaggregated into average customers and water-intensive customers	Average customer demand based on projected demand per customer (assumed equal to mean historical demand per customer) multiplied by the projected number of customers by subsector (proportionally projected with population). Water-intensive user demand forecast based on case-by-case projection of future demand (i.e. proportionally projected with population or constant).	Demand associated with high water users in the industrial sector as ML/a; demand for high users assumed to be represented by an average consumption rate for each user (ML/a) averaged over either the 2004–2006 historical period, or just using the historical 2006 value. The choice of averaging period depends on the test of the ratio of the standard deviation to mean of the last three year's consumption rates. If that ratio <0.5, then the 2004–2006 period is used, whereas if the ratio is >=0.5, just the 2006 value is used. This is to account for high variance that may be experienced over the 2004–2006 period. High users are forecast based on either a scaled constant (between 0 and 5), or pegged to population growth to represent the emergent demand associated with future high water users of that land-use type. Demand associated with average users in the industrial sector as ML/a; demand for average users assumed to be represented by an average consumption value (ML/location/a) multiplied by the forecast number of average user lots in a given future year

Baseline component	*Description*	*Notes*	*Assumptions*
Institutional	Baseline component for the institutional sector, including government, medical and educational customers	Institutional medical, educational and governmental customer demand forecast based on projected demand per customer (assumed equal to mean historical demand per customer) multiplied by the projected number of customers by subsector (proportionally projected with population). Water-intensive user demand based on case-by-case projection of future demand (i.e. proportionally projected with population or constant).	Demand associated with government subsector users within the institutional sector as ML/a; demand for this subsector assumed to be represented by an average consumption value (ML/location/a) multiplied by the forecast number of subsector lots in a given future year. Demand associated with health and medical subsector users within the institutional sector as ML/a; demand for this subsector assumed to be represented by an average consumption value (ML/location/a) multiplied by the forecast number of subsector lots in a given future year. Demand associated with education subsector users within the institutional sector as ML/a; demand for this subsector assumed to be represented by an average consumption value (ML/location/a) multiplied by the forecast number of subsector lots in a given future year. Demand associated with 'other' subsector users within the institutional sector as ML/a; demand for this subsector assumed to be represented by an average consumption value (ML/location/a) multiplied by the forecast number of subsector lots in a given future year. Demand associated with high water users within the institutional sector as ML/a; demand for high users assumed to be represented by an average consumption rate for each user (ML/a) averaged over either the 2004–2006 historical period, or just using the historical 2006 value. The choice of averaging period depends on the test of the ratio of the standard deviation to mean of the last three year's consumption rates. If that ratio <0.5, then the 2004–2006 period is used, whereas if the ratio >=0.5, just the 2006 value is used. This is to account for high variance that may be experienced over the 2004–2006 period. High users are forecast based on either a scaled constant (between 0 and 5), or pegged to population growth to represent the emergent demand associated with future high water users of that land-use type.

Baseline component	*Description*	*Notes*	*Assumptions*
Recreational	Baseline component for the recreational sector, comprising parks, open spaces and playing fields	Parks, open spaces, playing fields demand forecast based on projected demand per customer (assumed equal to mean historical demand per customer) multiplied by the projected number of customers by subsector (proportionally projected with population). Water intensive user demand based on case-by-case projection of future demand (i.e. proportionally projected with population or constant).	Demand associated with the sporting fields users within the recreational sector as ML/a; demand for this subsector assumed to be represented by an average consumption value (ML/location/a) multiplied by the forecast number of subsector lots in a given future year. Demand associated with the extensive area users within the recreational sector as ML/a; demand for this subsector assumed to be represented by an average consumption value (ML/location/a) multiplied by the forecast number of subsector lots in a given future year. Demand associated with the ‘other’ users within the recreational sector as ML/a; demand for this subsector assumed to be represented by an average consumption value (ML/location/a) multiplied by the forecast number of subsector lots in a given future year.
Other Residential	Non-residential end-use model baseline component for the ‘other residential’ sector, comprising hotels/motels, institutional accommodation, other customers and water-intensive customers	Hotels/motels, institutional accommodation, other customer demand forecast based on projected demand per customer (assumed equal to mean historical demand per customer) multiplied by the projected number of customers by subsector (proportionally projected with population). Water-intensive user demand based on case-by-case projection of future demand (i.e. proportionally projected with population or constant).	Demand associated with hotel/motel users in the ‘other residential’ sector as ML/a; demand for this subsector assumed to be represented by an average consumption value (ML/location/a) multiplied by the forecast number of subsector lots in a given future year. Demand associated with institutional accommodation users in the ‘other residential’ sector as ML/a; demand for this subsector assumed to be represented by an average consumption value (ML/location/a) multiplied by the forecast number of subsector lots in a given future year. Demand associated with ‘other’ users in the ‘other residential’ sector as ML/a; demand for this subsector assumed to be represented by an average consumption value (ML/location/a) multiplied by the forecast number of subsector lots in a given future year. Demand associated with high water users within the ‘other residential’ sector as ML/a; demand for high users assumed to be represented by an average consumption rate for each user (ML/a) averaged over either the 2004–2006 historical period, or just using the historical 2006 value. The choice of averaging period depends on the test of the ratio of the standard deviation to mean of the last three year’s consumption rates. If that ratio <0.5, then the 2004–2006 period is used, whereas if the ratio >=0.5, just the 2006 value is used. This is to account for high variance that may be experienced over the 2004–2006 period. High users are forecast based on either a scaled constant (between 0 and 5), or pegged to population growth to represent the emergent demand associated with future high water users of that land-use type.

Baseline component	*Description*	*Notes*	*Assumptions*
Res Sinks	Baseline component for kitchen sinks in residential dwellings	Based on product of projected residential household numbers and mean consumption.	Phosphorus consumed by end use is assumed to be 0.1485 grams per activity; based on Patterson (2004) stating that handwashing detergents contain approximately 11 mg/L. Mean frequency of appliance usage as uses per person per day; based on stock usage survey in Melbourne (Roberts 2004) finding 5.9 uses per week for dwellings with a machine and 10.1 uses per week for dwellings without a machine. Mean consumption of water is assumed to be 13.5 L per use; based on average filled capacity 25 L filled to an average 54% filled volume (Roberts 2004), with the remaining rinsing component calibrated against a historical end-use study in Perth (MWA 1985). The output estimates 50:50 split for filling:flowing activity types, which is consistent with the findings of a study in the United Kingdom (Friedler & Butler 1996). Proportion of end-use potable water demand that is hot water is assumed to be 0.463414634146341; based on assumed mean delivery temperature of 40 degrees Celsius. Proportion of end-use potable water demand that is wastewater is assumed to be 1; assumes all input water flows diverted to wastewater.
Res Showers	Baseline component for the showers in residential dwellings	Based on product of projected residential household numbers, mean shower frequency, and mean flow-rate for efficient and inefficient showers.	Lifetime of appliance for stock modelling is assumed to be 13 years; based on sales data and information from manufacturers (ECU 1995 Decade 2nd year report). Mean frequency of appliance usage is assumed to be 0.85 uses per person per day; based upon Yarra Valley end-use measurement study (Roberts 2005); response deemed more accurate than 2004 and 1999 study. Mean number of appliances per household as appliances per household; based upon modelling undertaken by Wilkenfeld (unpublished). Mean duration of appliance operation per use is assumed to be 7 minutes per use; based on two studies that independently found similar means in Perth (Loh & Coghlin 2003) and Melbourne (Roberts 2005). Both studies also found no observed difference in shower duration between those with normal and efficient showerheads. Mean flow rate during appliance operation as litres per minute; based upon end-use measurement survey of Melbourne (Roberts 2005). Proportion of end-use potable water demand that is hot water is assumed to be 0.463414634146341; based on assumed mean delivery temperature of 40 degrees Celsius. Proportion of end-use potable water demand that is wastewater is assumed to be 1; assumes all input water flows diverted to wastewater. Total number of inefficient appliances installed within the region as appliances; based on assumed maximum efficient appliance penetration of 40% (no further sales growth).

Baseline component	*Description*	*Notes*	*Assumptions*
Res Baths	Baseline component for baths in residential dwellings	Based on product of projected residential household numbers, mean bath usage frequency and mean bath volume.	Mean frequency of appliance usage is assumed to be 0.067 uses per person per day; based upon frequencies drawn from appliance usage and stock survey of Melbourne (Roberts 2004), which found an average of 2 and 0.2 baths per week for residents under and over the age of 12, respectively, adjusted for the local age distribution. Mean consumption of water is assumed to be 112.5 L per use; based on average bath capacity and fill volumes from an appliance usage and stock survey of Melbourne (Roberts 2004), which found an average capacity of 200 L, with fill volumes of 35% and 60% for residents under and over the age of 12 years, respectively, adjusted for the local age distribution. Proportion of end-use potable water demand that is hot water is assumed to be 0.585365853658537; assumes mean delivery temperature of 45 degrees Celsius. Proportion of end-use potable water demand that is wastewater is assumed to be 1; assumes all input water flows diverted to wastewater.
Res Basins	Baseline component for bathroom basins in residential dwellings	Based on product of projected residential household numbers, mean basin use frequency, mean basin use duration and mean basin flow rate.	Mean frequency of appliance usage is assumed to be 5.5 uses per person per day; based on appliance stock and usage pattern surveys in Melbourne (Roberts 2004). Mean duration of appliance operation per use is assumed to be 0.33 minutes per use; based on appliance stock and usage pattern surveys in Melbourne (Roberts 2004). Mean flow rate during appliance operation is assumed to be 4.9 L per minute; based on appliance stock and usage pattern surveys in Melbourne (Roberts 2004). Proportion of end-use potable water demand that is hot water is assumed to be 0.585365853658537; assumes mean delivery temperature of 45 degrees Celsius. Proportion of end-use potable water demand that is wastewater is assumed to be 1; assumes all input water flows diverted to wastewater.
Res Dishwashers	Baseline component for dishwashing machines in residential dwellings	Based on product of projected residential household numbers, projected dishwasher penetration, projected usage frequency, and mean consumption.	Mean frequency of appliance use as activities per household per year; based on linear modelled relationship between occupancy and dishwasher frequency for Melbourne (Roberts 2004), adjusted for local single residential household occupancy. Mean frequency of appliance use as activities per household per year; based on linear modelled relationship between occupancy and dishwasher frequency for Melbourne (Roberts 2004), adjusted for local multiresidential household occupancy.

Baseline component	*Description*	*Notes*	*Assumptions*
Res WaterHeaters	Baseline component for water heating in residential dwellings	Based on physical model of water heating energy for electric, gas and solar water heaters.	Proportion of appliance stock that is electric; based on state-specific ABS data (ABS 2005 4602.0) Proportion of appliance stock that is gas; based on state-specific ABS data (ABS 2005 4602.0) Proportion of appliance stock that is solar; based on state-specific ABS data (ABS 2005 4602.0) The electric energy required by the entire water heater mix to heat a unit of water to thermostat temperature is assumed to be 195.43793877551 gigajoules per megalitre; based on the product of the specific heat capacity of water (4.18 MJ/kL/deg C), the temperature increase (mean distribution temp = 21° to mean thermostat temp of 62°) divided by the heating efficiency (98%) plus additional losses in internal piping (100 MJ/kL) The gas energy required by the entire water heater mix to heat a unit of water to thermostat temperature is assumed to be 78.5130933333333 gigajoules per megalitre; based on the product of the specific heat capacity of water (4.18 MJ/kL/deg C), the temperature increase (mean distribution temp = 21° to mean thermostat temp of 62°) divided by the heating efficiency (75%) plus additional losses in internal piping (100 MJ/kL)

Appendix 1B: Option details and assumptions

1B.1 Summary table of option assumptions

	Options	*Description*	*Program time (years)*		*Target group*	*Water savings (kL/hh/a)*	*Percentage of target group participating*		*Costs*	
			S1	*S2*			*S1*	*S2*	*S1*	*S2*
1	Showerhead swap	Householders bring their old showerhead to a shopfront location and swap it for a new one, free of charge	4	–	Existing inefficient households	12	50%	–	Unit cost $40, utility pays $40 Initial mktg $5000 Ongoing mktg $10 000/yr Admin 0.2 FTE, PM 0.1 FTE	–
2	Residential retrofit	Plumber visit—replace showerheads, install tap flow regulators (kitchen & bathroom), toilet displacement device or cistern weight in single-flush toilets; check for leaks and provide	–	4	Existing inefficient households	22	–	50%	–	Unit cost $150,utility pays $120 Initial mktg $5000 Ongoing mktg $10 000/yr Admin 0.2 FTE, PM 0.1 FTE
3	Toilets replacement (currently underway in Wagga)	Complete toilet replacement	2	4	Existing inefficient households	22	10%	20%	Unit cost $600, utility pays $350 Initial mktg $5000 Ongoing mktg $10 000/yr Admin 0.2 FTE, PM 0.1 FTE	Unit cost $600, utility pays $350 Initial mktg $5000 Ongoing mktg $10 000/yr Admin 0.2 FTE, PM 0.1 FTE

	Options	Description	Program time (years)		Target group	Water savings (kL/hh/a)	Percentage of target group participating		Costs	
			S1	S2			S1	S2	S1	S2
4	Clothes washer rebate	Rebate for replacing top loaders with 5-star front loaders	4	4	All baseline appliance sales	15	75%	75%	Unit cost $150, utility pays $150 (assumes no additional cost to customer) Initial mktg $5000 Ongoing mktg $10 000/yr Admin 0.2 FTE, PM 0.1 FTE	Unit cost $150, utility pays $150 (assumes no additional cost to customer) Initial mktg $5000 Ongoing mktg $10 000/yr Admin 0.2 FTE, PM 0.1 FTE
5	Evaporative coolers	Maintenance visit and education campaign (turn them down, turn them off when not at home)	2	4	Existing households	28 (eng. estimate duration 6→4 hrs, continuous bleed coolers tuned to optimal flow rate of 2 L/min)	10%	40%	Unit cost $90, utility pays $90 Initial mktg $5000 Ongoing mktg $10 000/yr Evaluation $35 000 (over 2 years) Admin 0.2 FTE, PM 0.1 FTE	Unit cost $90, utility pays $90 Initial mktg $5000 Ongoing mktg $10 000/yr Evaluation $35 000 (over 2 years) Admin 0.2 FTE, PM 0.1 FTE
6	Residential nature strips (currently underway in Wagga)	Rebate for relandscaping of nature strip; ban watering of nature strips	2	4	Existing households	52 (eng. estimate 60 m^2 lawn converted to hardy garden)	5%	10%	Unit cost $1400, ($10 per m^2 of irrigated turf), utility pays $700 Initial mktg $50 000 Ongoing mktg $50 000/yr Evaluation $35 000 (over 2 years) Admin 0.05 FTE, PM 0 FTE	Unit cost $1400, ($5–$10 per m^2 of irrigated turf), utility pays $700 Initial mktg $50 000 Ongoing mktg $50 000/yr Evaluation $35 000 (over 2 years) Admin 0.05 FTE, PM 0 FTE

	Options	Description	Program time (years)		Target group	Water savings (kL/hh/a)	Percentage of target group participating		Costs	
			S1	S2			S1	S2	S1	S2
7	Outdoor watering DCP	DCP banning irrigated lawns	Ongoing		New households	122 (eng est. 150 m² lawn converted to hardy garden)	–	100%	–	Unit cost $0, utility pays $0 Initial mktg $5000 Ongoing mktg $1000/yr Evaluation $35 000 (over 2 years) Admin 0.05 FTE, PM 0 FTE
8	Rainwater tank rebate (currently available)	5-kL tank retrofit for existing residential for toilets, washing machines and outdoor	4		Existing households	38	–	10%	–	Unit cost $2700, utility pays $500 Initial mktg $5000 Ongoing mktg $10 000/yr Evaluation $35 000 (over 2 years) Admin 0.2 FTE, PM 0.1 FTE
9	Permanent water conservation measures (currently underway in Wagga)	No fixed sprinklers allowed between 10 a.m. and 5 p.m. All requested to reduce water consumption by 20%	Ongoing		All residential (portfolio 1) / All existing residential (portfolio 2)	~80 (eng estimate assumes 4% reduction in landscape demand)	100%	100%	Initial mktg $10 000 Ongoing mktg $5000/yr Admin 0.1 FTE	Initial mktg $10 000 Ongoing mktg $5000/yr Admin 0.1 FTE
10	Non-revenue	Leak detection and repair, pressure management program (from SWC program)	Ongoing		Utility	20% reduction in forecast NRW			$0.32/kL leak real losses avoided	

	Options	Description	Program time (years)		Target group	Water savings (kL/hh/a)	Percentage of target group participating		Costs	
			S1	S2			S1	S2	S1	S2
11	Water audit—hotels	Water audit, install efficient fixtures and sensors and carry out air-conditioning maintenance. 49 (hotels/motels)	2	4	Hotels/motels	20% reduction ~0.9 ML/a	30%	80%	Unit cost $800, utility pays $800 Initial mktg $5000 Ongoing mktg $20 000/yr Evaluation $35 000 (over 2 years) Admin 0.2 FTE, PM 0.1 FTE (prior evaluated cost of $4600/ML)	Unit cost $800, utility pays $800 Initial mktg $5000 Ongoing mktg $30 000/yr Evaluation $35 000 (over 2 years) Admin 0.2 FTE, PM 0.1 FTE (prior evaluated cost of $4600/ML)
12	Water audit—schools	Monitoring, alarm systems for leaks plus education. 36 schools (five regions)	4	4	Schools	SWC leak detection/ monitoring program saves 5.3 ML/school/a	100%	100%	Unit cost $4000, utility pays $4000 Initial mktg $5000 Ongoing mktg $20 000/yr Evaluation $35 000 (over 2 years) Admin 0.2 FTE, PM 0.1 FTE (prior evaluated cost of $4600/ML)	Unit cost $4000, utility pays $4000 Initial mktg $5000 Ongoing mktg $20 000/yr Evaluation $35 000 (over 2 years) Admin 0.2 FTE, PM 0.1 FTE (prior evaluated cost of $4600/ML)
13	Water audit—industrial customers	Water audits and modifications for 5 high water users	2	2	Large industrial users	20% reduction	100%	100%	Unit cost $15000, utility pays $75000 Initial mktg $5000 Ongoing mktg $10 000/yr Evaluation $5000 Admin 0.2 FTE, PM 0.1 FTE (prior evaluated cost of $3000/ML)	Unit cost $15 000, utility pays $75000 Initial mktg $5000 Ongoing mktg $10 000/yr Evaluation $5000 Admin 0.2 FTE, PM 0.1 FTE (prior evaluated cost of $3000/ML)

	Options	Description	Program time (years)		Target group	Water savings (kL/hh/a)	Percentage of target group participating		Costs	
			S1	S2			S1	S2	S1	S2
14	Commercial nature strips	Rebate for relandscaping of commercial properties	4	4	Commercial properties with lawns	243 kL/lot/yr (engineering estimate: 300 m^2 lawn converted to hardy garden)	20%	20%	Unit cost $1500 ($5 per m^2 of irrigated turf), utility pays $1000 Initial mktg $5000 Ongoing mktg $10 000/yr Evaluation $35 000 (over 2 years) Admin 0.2 FTE, PM 0.1 FTE	Unit cost $1500, utility pays $1000 Initial mktg $5000 Ongoing mktg $10 000/yr Evaluation $35 000 (over 2 years) Admin 0.2 FTE, PM 0.1 FTE

1B.2 Detailed table of option assumptions

Components in Wagga Wagga	*Description*	*Assumptions*
DS Residential Shower Swap S1	Householders bring their old showerhead to a shopfront location and swap it for a new one, free of charge	The proportion of the targeted customers who participate in the program is assumed to be 0.5; internal estimate. The component of the unit costs incurred per participant that is provided by the utility (excluding the contribution from the participant) is assumed to be $40 per unit; assumes full subsidy by utility. Water yield per installed unit is assumed to be 12 kL per participant per annum; based on review of evaluated programs implemented in Melbourne (Fyfe et al. 2009, Lee et al. 2007). Proportion of an administrator’s annual working time assigned to the option is assumed to be 0.2 full time equivalents (FTE); internal estimate. Proportion of a project manager’s annual working time assigned to the option is assumed to be 0.1 FTE; internal estimate. Defined initial cost of marketing the program excluding ongoing and staff costs is assumed to be $5000; internal estimate. Defined ongoing cost of marketing the program each year excluding initial and staff costs is assumed to be $10 000 per annum; internal estimate. Share of water savings that are also wastewater savings is assumed to be 1; assumes all potable water savings also occur as wastewater savings. Share of water savings that are also hot water savings is assumed to be 0.463414634146341; based on assumed operating temperature in baseline assumptions.
DS Residential Toilet Replacement S2	Complete toilet replacement	The proportion of the targeted customers who participate in the program is assumed to be 0.2; internal estimate. Water yield per installed unit is assumed to be 22 kL per participant per annum; based on a review of evaluated programs implemented at the gold coast (Snelling et al. 2006), and the ACT (Fyfe et al. 2009, Lee et al. 2008). Proportion of an administrator’s annual working time assigned to the option is assumed to be 0.2 FTE; internal estimate. Proportion of a project manager’s annual working time assigned to the option is assumed to be 0.1 FTE; internal estimate. Defined initial cost of marketing the program excluding ongoing and staff costs is assumed to be $5000; internal estimate. Defined ongoing cost of marketing the program each year excluding initial and staff costs is assumed to be $10 000 per annum; internal estimate. Specified cost to evaluate the savings of the program (split into two payments: one year after first year and one year after completion) as dollars per program; internal estimate.

Components in Wagga Wagga	*Description*	*Assumptions*
DS Residential Clothes Washer rebate S1S2	Rebate program for replacing top-loaders with 5-star front-loaders	The proportion of the targeted customers who participate in the program is assumed to be 0.75; internal estimate. The component of the unit costs incurred per participant that is provided by the utility (excluding the contribution from the participant) is assumed to be $150 per unit; based on similar programs implemented in major cities. Water yield per installed unit is assumed to be 15 kL per participant per annum; based on evaluated savings for a similar program implemented at the Gold Coast (Snelling et al. 2006). The component of the unit costs incurred per participant that is provided by the customer as dollars per participant; based on the assumption that all sales would have occurred otherwise and therefore no net incremental cost to the customer. Proportion of an administrator’s annual working time assigned to the option is assumed to be 0.2 FTE; internal estimate. Proportion of a project manager’s annual working time assigned to the option is assumed to be 0.1 FTE; internal estimate. Defined initial cost of marketing the program excluding ongoing and staff costs is assumed to be $5000; internal estimate. Defined ongoing cost of marketing the program each year excluding initial and staff costs is assumed to be $10 000 per annum; internal estimate. Specified cost to evaluate the savings of the program (split into two payments: one year after first year and one year after completion) as dollars per program; internal estimate.
DS Hotels S1	Water audit, install efficient fixtures and sensors and carry out air-conditioning maintenance. 49 hotels/motels	The proportion of the targeted customers that participate in the program is assumed to be 0.3; internal estimate. The component of the unit costs incurred per participant that is provided by the utility (excluding the contribution from the participant) is assumed to be $800 per unit; internal estimate. The component of the unit costs incurred per participant that is provided by the customer, as dollars per participant; internal estimate. Proportion of an administrator’s annual working time assigned to the option is assumed to be 0.2 FTE; internal estimate. Proportion of a project manager’s annual working time assigned to the option is assumed to be 0.1 FTE; internal estimate. Defined initial cost of marketing the program excluding ongoing and staff costs is assumed to be $5000; internal estimate. Defined ongoing cost of marketing the program each year excluding initial and staff costs is assumed to be $20 000 per annum; internal estimate. Specified cost to evaluate the savings of the program (split into two payments: one year after first year and one year after completion) as dollars per program; internal estimate. The proportionate reduction in mean customer demand attributable to the program is assumed to be 0.2%; internal estimate. Share of water savings that are also wastewater savings is assumed to be 0.8; ISF estimate. Share of water savings that are also hot water savings is assumed to be 0.3; ISF estimate.

Components in Wagga Wagga	*Description*	*Assumptions*
DS Hotels S2	Water audit, install efficient fixtures and sensors and carry out air-conditioning maintenance. 49 hotels/motels	The proportion of the targeted customers that participate in the program is assumed to be 0.8; internal estimate. The component of the unit costs incurred per participant that is provided by the utility (excluding the contribution from the participant) is assumed to be $800 per unit; internal estimate. The component of the unit costs incurred per participant that is provided by the customer, as dollars per participant; internal estimate. Proportion of an administrator's annual working time assigned to the option is assumed to be 0.2 FTE; internal estimate. Proportion of a project manager's annual working time assigned to the option is assumed to be 0.1 FTE; internal estimate. Defined initial cost of marketing the program excluding ongoing and staff costs is assumed to be $5000; internal estimate. Defined ongoing cost of marketing the program each year excluding initial and staff costs is assumed to be $30 000 per annum; internal estimate. Specified cost to evaluate the savings of the program (split into two payments: one year after first year and one year after completion) as dollars per program; internal estimate. The proportionate reduction in mean customer demand attributable to the program is assumed to be 0.2%; internal estimate. Share of water savings that are also wastewater savings is assumed to be 0.8; ISF estimate. Share of water savings that are also hot water savings is assumed to be 0.3; ISF estimate.
DS Industrial S1S2	Water audits and modifications for five high water users	The proportion of the targeted customers that participate in the program is assumed to be 1; internal estimate. The component of the unit costs incurred per participant that is provided by the utility (excluding the contribution from the participant) is assumed to be $75 000 per unit; internal estimate. The component of the unit costs incurred per participant that is provided by the customer is assumed to be $75 000 per participant; internal estimate. Proportion of an administrator's annual working time assigned to the option is assumed to be 0.2 FTE; internal estimate. Proportion of a project manager's annual working time assigned to the option is assumed to be 0.1 FTE; internal estimate. Defined initial cost of marketing the program excluding ongoing and staff costs is assumed to be $5000; internal estimate. Defined ongoing cost of marketing the program each year excluding initial and staff costs is assumed to be $10 000 per annum; internal estimate. Specified cost to evaluate the savings of the program (split into two payments: one year after first year and one year after completion) as dollars per program; internal estimate. The proportionate reduction in mean customer demand attributable to the program is assumed to be 0.2%; internal estimate.

Components in Wagga Wagga	*Description*	*Assumptions*
DS Schools S1S2	Monitoring, alarm systems for leaks plus education. 36 schools	The proportion of the targeted customers that participate in the program is assumed to be 0.8; internal estimate. Proportion of an administrator's annual working time assigned to the option is assumed to be 0.2 FTE; internal estimate. Proportion of a project manager's annual working time assigned to the option is assumed to be 0.1 FTE; internal estimate. Defined initial cost of marketing the program excluding ongoing and staff costs is assumed to be $5000; internal estimate. Defined ongoing cost of marketing the program each year excluding initial and staff costs is assumed to be $20 000 per annum; internal estimate. Specified cost to evaluate the savings of the program (split into two payments: one year after first year and one year after completion) is assumed to be $35 000 per program; internal estimate. The proportionate reduction in mean customer demand attributable to the program is assumed to be 0.2%; internal estimate. Share of water savings that are also wastewater savings is assumed to be 0.6; ISF estimate. Share of water savings that are also hot water savings is assumed to be 0.05; ISF estimate.
DS Commercial Nature strips S1S2	Rebate for relandscaping of commercial properties	The proportion of the targeted customers that participate in the program is assumed to be 0.2; internal estimate. The component of the unit costs incurred per participant that is provided by the utility (excluding the contribution from the participant) is assumed to be $1000 per unit; assumes partial subsidy. Water yield per installed unit is assumed to be 243 kL per participant per annum; based on mean nature strip area of 300 m^2 lawn converted to hardy native garden. Proportion of an administrator's annual working time assigned to the option is assumed to be 0.2 FTE; internal estimate. Proportion of a project manager's annual working time assigned to the option is assumed to be 0.1 FTE; internal estimate. Defined initial cost of marketing the program excluding ongoing and staff costs is assumed to be $5000; internal estimate. Specified cost to evaluate the savings of the program (split into two payments: one year after first year and one year after completion) is assumed to be $35 000 per program; internal estimate. Unit cost attributed to each participating customer is assumed to be $1500 per participant; assumes $5 per square metre converted.

Components in Wagga Wagga	*Description*	*Assumptions*
DS PermWatCon-Measures S1	No fixed sprinklers allowed between 10 a.m. and 5 p.m. All requested to reduce water consumption by 20%	The proportion of the targeted customers who participate in the program is assumed to be 1; internal estimate. The component of the unit costs incurred per participant that is provided by the utility (excluding the contribution from the participant) as dollars per unit; internal estimate. The component of the unit costs incurred per participant that is provided by the customer as dollars per participant; internal estimate. Proportion of an administrator's annual working time assigned to the option is assumed to be 0.1 FTE; internal estimate. Proportion of a project manager's annual working time assigned to the option as FTE; internal estimate. Defined initial cost of marketing the program excluding ongoing and staff costs is assumed to be %10 000; internal estimate. Defined ongoing cost of marketing the program each year excluding initial and staff costs is assumed to be $5000 per annum; internal estimate. Specified cost to evaluate the savings of the program (split into two payments: one year after first year and one year after completion) as dollars per program; internal estimate. The proportionate reduction in mean customer demand attributable to the program is assumed to be 0.04%; internal estimate.
DS Residential Nature Strips S1	Rebate for relandscaping of nature strip; ban on watering of nature strips	The proportion of the targeted customers who participate in the program is assumed to be 0.05; internal estimate. The component of the unit costs incurred per participant that is provided by the utility (excluding the contribution from the participant) is assumed to be $700 per unit; internal estimate. Water yield per installed unit is assumed to be 52 kL per participant per annum; based on modelled with irrigation water balance model substituting hardy natives for a 60 m² grass nature strip. The component of the unit costs incurred per participant that is provided by the customer is assumed to be $700 per participant; internal estimate. Proportion of an administrator's annual working time assigned to the option is assumed to be 0.2 FTE; internal estimate. Proportion of a project manager's annual working time assigned to the option is assumed to be 0.1 FTE; internal estimate. Defined initial cost of marketing the program excluding ongoing and staff costs is assumed to be $50 000; internal estimate. Defined ongoing cost of marketing the program each year excluding initial and staff costs is assumed to be $50 000 per annum; internal estimate. Specified cost to evaluate the savings of the program (split into two payments: one year after first year and one year after completion) is assumed to be $35 000 per program; internal estimate.

Components in Wagga Wagga	*Description*	*Assumptions*
DS Residential Nature Strips S2	Rebate for relandscaping of nature strip; ban on watering of nature strips	The proportion of the targeted customers who participate in the program is assumed to be 0.1; internal estimate. Water yield per installed unit is assumed to be 52 kL per participant per annum; based on modelled within irrigation water balance model substituting hardy natives for a 60 m² grass nature strip. Proportion of an administrator's annual working time assigned to the option is assumed to be 0.2 FTE; internal estimate. Proportion of a project manager's annual working time assigned to the option is assumed to be 0.1 FTE; internal estimate. Defined initial cost of marketing the program excluding ongoing and staff costs is assumed to be $50 000; internal estimate. Defined ongoing cost of marketing the program each year excluding initial and staff costs is assumed to be $50 000 per annum; internal estimate. Specified cost to evaluate the savings of the program (split into two payments: one year after first year and one year after completion) is assumed to be $35 000 per program; internal estimate.
DS Residential Lawns DCP S2	DCP banning irrigated lawns	The proportion of the targeted customers who participate in the program is assumed to be 1; internal estimate. Water yield per installed unit is assumed to be 122 kL per participant per annum; based on irrigation savings calculator assuming 150 m² turf replaced with hardy native garden. Proportion of an administrator's annual working time assigned to the option is assumed to be 0.05 FTE; internal estimate. Proportion of a project manager's annual working time assigned to the option as FTE; internal estimate. Defined initial cost of marketing the program excluding ongoing and staff costs is assumed to be $5000; internal estimate. Specified cost to evaluate the savings of the program (split into two payments: one year after first year and one year after completion) as dollars per program; internal estimate.

Components in Wagga Wagga	*Description*	*Assumptions*
DS Residential Evaporative Coolers S1	Maintenance visit and education campaign (turn them down, turn them off when not at home)	The proportion of the targeted customers who participate in the program is assumed to be 0.1; internal estimate. The component of the unit costs incurred per participant that is provided by the utility (excluding the contribution from the participant) is assumed to be $90 per unit; based on phone conversations with air-conditioning installers in Wagga. Water yield per installed unit is assumed to be 28 kL per participant per annum; based on end-use assumptions, assumes reduced mean usage per day from 6 hrs to 4 hrs. Proportion of an administrator's annual working time assigned to the option is assumed to be 0.2 FTE; internal estimate. Proportion of a project manager's annual working time assigned to the option is assumed to be 0.1 FTE; internal estimate. Defined initial cost of marketing the program excluding ongoing and staff costs is assumed to be $5000; internal estimate. Defined ongoing cost of marketing the program each year excluding initial and staff costs is assumed to be $10 000 per annum; internal estimate. Specified cost to evaluate the savings of the program (split into two payments: one year after first year and one year after completion) is assumed to be $35 000 per program; internal estimate.
DS Residential Evaporative Coolers S2	Maintenance visit and education campaign (turn them down, turn them off when not at home)	The proportion of the targeted customers who participate in the program is assumed to be 0.4; internal estimate. Proportion of an administrator's annual working time assigned to the option is assumed to be 0.2 FTE; internal estimate. Proportion of a project manager's annual working time assigned to the option is assumed to be 0.1 FTE; internal estimate. Defined initial cost of marketing the program excluding ongoing and staff costs is assumed to be $5000; internal estimate. Defined ongoing cost of marketing the program each year excluding initial and staff costs is assumed to be $10 000 per annum; internal estimate. Specified cost to evaluate the savings of the program (split into two payments: one year after first year and one year after completion) is assumed to be $35 000 per program; internal estimate.

Components in Wagga Wagga	*Description*	*Assumptions*
DS Residential Toilet Replacement S1	Complete toilet replacement	The proportion of the targeted customers who participate in the program is assumed to be 0.1; internal estimate. Water yield per installed unit is assumed to be 22 kL per participant per annum; based on a review of evaluated programs implemented at the Gold Coast (Snelling et al. 2006), and the ACT (Fyfe et al. 2009, Lee et al. 2008). Proportion of an administrator's annual working time assigned to the option is assumed to be 0.2 FTE; internal estimate. Proportion of a project manager's annual working time assigned to the option is assumed to be 0.1 FTE; internal estimate. Defined initial cost of marketing the program excluding ongoing and staff costs is assumed to be $5000; internal estimate. Defined ongoing cost of marketing the program each year excluding initial and staff costs is assumed to be $10 000 per annum; internal estimate. Specified cost to evaluate the savings of the program (split into two payments: one year after first year and one year after completion) as dollars per program; internal estimate.
DS Residential Rainwater Tanks S2	5-kL tank retrofit for existing residential for toilets, washing machines and outdoor uses	The proportion of the targeted customers who participate in the program is assumed to be 0.1; internal estimate. Water yield per installed unit is assumed to be 38 kL per participant per annum; based on rainwater tank model using 2.6 occupancy, 6/3 toilet, 210 m² landscape area, 5 kL tank, 150 m² roof catchment area, plumbed to irrigation and toilet. Proportion of an administrator's annual working time assigned to the option is assumed to be 0.2 FTE; internal estimate. Proportion of a project manager's annual working time assigned to the option is assumed to be 0.1 FTE; internal estimate. Defined initial cost of marketing the program excluding ongoing and staff costs is assumed to be $5000; internal estimate. Defined ongoing cost of marketing the program each year excluding initial and staff costs is assumed to be $10 000 per annum; internal estimate. Specified cost to evaluate the savings of the program (split into two payments: one year after first year and one year after completion) is assumed to be $35 000 per program; internal estimate.

Components in Wagga Wagga	*Description*	*Assumptions*
DS Residential Retrofit S2	Plumber visit—replace showerheads, install tap flow regulators (kitchen & bathroom), toilet displacement device or cistern weight in single flush toilets; check for leaks and provide advice	The proportion of the targeted customers who participate in the program is assumed to be 0.5; internal estimate. Water yield per installed unit is assumed to be 22 kL per participant per annum; based on evaluation of similar program (Fyfe et al. 2009, Lee et al. 2008, Sarac, Day and White 2002, Turner et al. 2005). Proportion of an administrator's annual working time assigned to the option is assumed to be 0.2 FTE; internal estimate. Proportion of a project manager's annual working time assigned to the option is assumed to be 0.1 FTE; internal estimate. Defined initial cost of marketing the program excluding ongoing and staff costs is assumed to be $5000; internal estimate. Defined ongoing cost of marketing the program each year excluding initial and staff costs is assumed to be $10 000 per annum; internal estimate. Specified cost to evaluate the savings of the program (split into two payments: one year after first year and one year after completion) as dollars per program; internal estimate.
DS Non-revenue Water	Leak detection and repair, pressure management program (from SWC program)	Proportion of an administrator's annual working time assigned to the option as FTE; internal estimate. Proportion of a project manager's annual working time assigned to the option as FTE; internal estimate. Costs borne by the customer as dollars per annum; internal estimate. Defined initial cost of marketing the program excluding ongoing and staff costs as dollars; internal estimate .
DS PermWatCon-Measures S2		Prohibits hosing down of hard surfaces (paths and driveways). Requires all hand held hoses to have a trigger nozzle. Prohibits irrigation by fixed sprinklers between the hours of 10 a.m. and 5 p.m.

Appendix 1C: Options results—cost breakdown

1C.1 S1 cost components

Options	*Customer costs*	*Customer benefits*	*Customer transfers*	*Utility costs*	*Utility benefits*	*Utility transfers*	*Societal net cost*
DS Commercial Nature strips S1S2	$89 408	–	–$846 533	$305 012	–$216 127	$846 533	$178 293
DS Hotels S1	–	–$605 512	–$203 147	$81 373	–$57 050	$203 147	–$581 189
DS Industrial S1S2	$301 957	–	–$2 960 150	$357 641	–$831 306	$2 960 150	–$171 708
DS Non-revenue water S1S2	–	–	–$2 201 575	$546 127	–$559 934	$2 201 575	–$13 807
DS PermWatConMeasures S1	–	–	–$2 983 042	$146 614	–$757 929	$2 983 042	–$611 315
DS Residential clothes washer rebate S1S2	–	–$1 557 241	–$636 061	$706 449	–$180 657	$636 061	–$1 031 450
DS Residential Evaporative Coolers S1	–	–	–$392 710	$146 584	–$99 880	$392 710	$46 704
DS Residential Nature Strips S1	$500 982	–	–$729 319	$684 930	–$185 492	$729 319	$1 000 420
DS Residential Shower Swap S1	–	–$3 547 194	–$777 279	$315 245	–$221 785	$777 279	–$3 453 734
DS Residential Toilet Replacement S1	$364 263	–	–$523 449	$565 653	–$149 831	$523 449	$780 085
DS Schools S1S2	–	–$303 895	–$608 126	$246 493	–$155 260	$608 126	–$212 662
Subtotal	$1 256 609	–$6 013 843	–$12 861 392	$4 102 121	–$3 415 252	$12 861 392	
Total	Customer net cost	–$17 618 625		Utility net cost	$13 548 261	Societal net cost	–$4 070 364

1C.2 S1 adjusted cost components

Options	*Customer costs*	*Customer benefits*	*Customer transfers*	*Utility costs*	*Utility benefits*	*Utility transfers*	*Societal net cost*
DS Commercial Nature strips S1S2	$89 408	–	–$846 533	$305 012	–$216 127	$846 533	$178 293
DS Hotels S1	–	–$605 512	–$203 147	$81 373	–$57 050	$203 147	–$581 189
DS Industrial S1S2	$301 957	–	–$2 960 150	$357 641	–$831 306	$2 960 150	–$171 708
DS Non-revenue water S1S2	–	–	–$2 201 575	$546 127	–$559 934	$2 201 575	–$13 807
DS PermWatConMeasures S1	–	–	–$2 983 042	$146 614	–$757 929	$2 983 042	–$611 315
DS Residential Clothes washer Rebate S1S2	–	–$1 557 241	–$636 061	$706 449	–$180 657	$636 061	–$1 031 450
DS Residential Evaporative Coolers S1	–	–	–$392 710	$146 584	–$99 880	$392 710	$46 704
DS Residential Nature Strips S1	$500 982	–	–$729 319	$684 930	–$185 492	$729 319	$1 000 420
DS Residential Shower Swap S1	–	–$3 547 194	–$777 279	$315 245	–$221 785	$777 279	–$3 453 734
DS Schools S1S2	–	–$303 895	–$608 126	$246 493	–$155 260	$608 126	–$212 662
Subtotal	$892 346	–$6 013 843	–$12 337 943	$3 536 468	–$3 265 421	$12 337 943	
Total	Customer net cost	–$17 459 439		Utility net cost	$12 608 990	Societal net cost	–$4 850 449

1C.3 S2 cost components

Options	*Customer costs*	*Customer benefits*	*Customer transfers*	*Utility costs*	*Utility benefits*	*Utility transfers*	*Societal net cost*
DS Commercial Nature strips S1S2	$89 408	–	–$846 533	$305 012	–$216 127	$846 533	$ 178 293
DS Hotels S2	–	–$1 529 626	–$510 157	$186 076	–$143 939	$510 157	–$1 487 490
DS Industrial S1S2	$301 957	–	–$2 960 150	$357 641	–$831 306	$2 960 150	–$ 171 708
DS Non-revenue water S1S2	–	–	–$2 201 575	$546 127	–$559 934	$2 201 575	–$ 13 807
DS PermWatConMeasures S2	–	–	–$2 776 668	$146 614	–$704 581	$2 776 668	–$ 557 967
DS Residential Clothes washer Rebate S1S2	–	–$1 557 241	–$636 061	$706 449	–$180 657	$636 061	–$1 031 450
DS Residential Evaporative Coolers S2	–	–	–$791 923	$370 092	–$60 990	$791 923	$309 102
DS Residential Lawns S2	–	–	–$2 787 679	$54 446	–$719 837	$2 787 679	–$665 391
DS Residential Nature Strips S2	$948 486	–	–$1 372 667	$1 233 359	–$350 455	$1 372 667	$1 831 390
DS Residential Rainwater Tanks S2	$2 980 957	–	–$1 003 103	$803 686	–$256 102	$1 003 103	$3 528 542
DS Residential Retrofit S2	$203 247	–$3 604 043	–$1 829 406	$914 194	–$522 103	$1 829 406	–$3 008 705
DS Residential Toilet Replacement S2	$662 600	–	–$884 552	$1 028 846	–$254 465	$884 552	$1 436 981
DS Schools S1S2	–	–$303 895	–$608 126	$246 493	–$155 260	$608 126	–$ 212 662
Subtotal	$5 186 656	–$6 994 806	–$19 208 602	$6 899 034	–$4 955 757	$19 208 602	
Total	Customer net cost	–$21 016 752		Utility net cost	$21 151 879	Societal net cost	$135 127

1C.4 S2 adjusted cost components

Options	*Customer costs*	*Customer benefits*	*Customer transfers*	*Utility costs*	*Utility benefits*	*Utility transfers*	*Societal net cost*
DS Commercial Nature strips S1S2	$89 408	–	–$846 533	$305 012	–$216 127	$846 533	$178 293
DS Hotels S2	–	–$1 529 626	–$510 157	$186 076	–$143 939	$510 157	–$1 487 490
DS Industrial S1S2	$301 957	–	–$2 960 150	$357 641	–$831 306	$2 960 150	–$171 708
DS Non-revenue water S1S2	–	–	–$2 201 575	$546 127	–$559 934	$2 201 575	–$13 807
DS PermWatConMeasures S2	–	–	–$2 776 668	$146 614	–$704 581	$2 776 668	–$557 967
DS Residential Clothes washer Rebate S1S2	–	–$1 557 241	–$636 061	$706 449	–$180 657	$636 061	–$1 031 450
DS Residential Evaporative Coolers S2	–	–	–$791 923	$370 092	–$60 990	$791 923	$309 102
DS Residential Lawns S2	–	–	–$2 787 679	$54 446	–$719 837	$2 787 679	–$665 391
DS Residential Nature Strips S2	$948 486	–	–$1 372 667	$1 233 359	–$350 455	$1 372 667	$1 831 390
DS Residential Retrofit S2	$203 247	–$3 604 043	–$1 829 406	$914 194	–$522 103	$1 829 406	–$3 008 705
DS Schools S1S2	–	–$303 895	–$608 126	$246 493	–$155 260	$608 126	–$212 662
Subtotal	$1 543 098	–$6 994 806	–$17 320 947	$5 066 503	–$4 445 190	$17 320 947	
Total	Customer net cost	–$ 22 772 654		Utility net cost	$ 17 942 259	Societal net cost	–$4 830 395